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Simple Decontamination Of Residential Areas McCoy III

by

J. C. Maloney

J. L. Meredith

NUCLEAR TESTING DIVISION

September 1962

U. S. ARMY

NUCLEAR DEFENSE LABORATORY

ARMY CHEMICAL CENTER • MARYLAND

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McCOY - III

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FOREWORD

This work was authorized under Work Order No. OCD-OS-62-43 by the Department of Defense, Office of Civil Defense, and by the Department of the Army, Chemical Corps Research and Development Command. The field effort was conducted during April and May 1962.

Acknowledgements

The authors wish to acknowledge the assistance of General Dynamics/Fort Worth in the field phase of the operation, and the assistance of the staff of Camp McCoy, Wisconsin, who provided timely logistic and maintenance support at the test site.

DIGEST

This project was conducted to determine the effectiveness achieved, the effort required, and the dose received by personnel in the use of simple decontamination procedures for the radiological recovery of residential areas [illegible].

A series of tests was conducted on small test plots at Camp McCoy, Wisconsin, with radioactive fallout simulant. Simple decontamination techniques employing household and garden tools were used. In addition, the radiological recovery of a small residence and surrounding lawn was effected.

The following conclusions are based on the experimental results:

(1) Simple decontamination methods such as sweeping, vacuum cleaning, and garden hosing are effective when applied to roofs and paved areas. Since these methods have relatively slow application rates, their employment will be limited by operator dose.

(2) Surface removal is the only effective simple method applicable to soil. Work rates are very low and will vary according to the soil condition; however, plowing with a garden tractor is applicable to adjacent areas or buffer zones.

(3) Effective radiological recovery of a small residence and lawn can be accomplished in a heavy fallout area, 2000 r/hr at H+1 hr, after a two-week waiting period. A one-man decontamination crew would receive a dose of approximately 25 r.

MILITARY APPLICATION

The information developed in this report is applicable to many military installation areas. In the event of a shortage of heavy equipment, the only alternative would be to employ simple decontamination methods, using generally available equipment.

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CONTENTS

SIMPLE DECONTAMINATION OF RESIDENTIAL AREAS

McCOY III

I. INTRODUCTION.

A. Objective.

The objective of this project was to determine the effectiveness achieved, the effort required, and the dose received by personnel in the use of simple decontamination procedures for the radiological recovery of residential areas.

B. Justification and Requirements.

Available technical manuals, such as TM 3-225[1], present methods and data necessary for planning decontamination operations in built-up areas; however, such planning is largely based on the use of heavy construction equipment, maintenance or fire fighting apparatus. If such equipment is not available, or if the water supply is limited, the only alternative may be in the individual employment of simple decontamination methods using generally available tools such as brooms, shovels, hoses, vacuum cleaners, and garden-type equipment.

C. Historical Background.

Although radiological decontamination has been intensively investigated during the past decade by many agencies, little effort has been expended in evaluating simple methods. Rather, the emphasis has been on evaluating high-output or rapid methods in order to keep operator doses at a minimum. Simple methods have been utilized only as an adjunct to mechanized operations where obstructions caused heavy equipment to miss small areas or where areas were so small that power equipment could not be operated.

II. OPERATIONAL PROCEDURES AND FACILITIES.

A. Operational Plan.

A series of decontamination trials (see table 1) was planned to be conducted at the Camp McCoy, Wisconsin, test site, which had been utilized for cold-weather decontamination tests. A description of the Camp McCoy test site is presented in references 2 and 3. Each decontamination trial was planned to be conducted on a nominal 20- by 100-foot area. In some cases the area size was modified to use available surfaces, or smaller areas were used for slow work-rate techniques to keep doses within limits.

TABLE 1

DECONTAMINATION TRIALS CONDUCTED

Type of surface contaminated	Method of decontamination
Sandy loam - grass	Garden rototill Garden plow Shovel scrape Spade (turn over) Vacuum clean Rotary mow, conventional Rotary mow, Toro
Strip shingle roof	Corn broom sweep Street broom sweep Vacuum clean Garden hose, 8 psi Garden hose, 35 psi
Macadam pavement	Corn broom sweep Street broom sweep Street broom sweep (in effort stages) Vacuum clean Garden hose, 35 psi
Concrete pavement	Corn broom sweep Street broom sweep Vacuum clean Garden hose, 35 psi
Asphalt pavement	Corn broom sweep Street broom sweep Vacuum clean Garden hose, 8 psi and 35 psi Garden hose, (35 psi in effort stages)

In addition, a small residential structure and 1/2 acre of surrounding lawn were contaminated in order to obtain logistic data on the integrated decontamination of this area by simple means.

Operations included preparing a radioactive fallout simulant, spreading the simulant on test surfaces, performing decontamination trials, and disposing of the radioactive waste.

B. Fallout Simulant.

The fallout simulant employed was 150μ to 300μ smooth sand, tagged with lanthanum-140 at a specific activity of 20μc/gm, and spread at a mass level of [illegible] gm/sq ft. This is the same simulant as used previously at Camp McCoy for the cold-weather decontamination studies.[2,3] References 2 and 3 contain detailed discussions on the choice of parameters and on the production of this fallout simulant. In this project spreading the simulant on test surfaces was done with Scott lawn spreaders (see figure 1).

C. Equipment and Decontamination Operations - Test Plots.

The following tools and power equipment were used in the various decontamination tests:

1. Street Broom

The street broom was made of fiber bristles attached to a wooden back and had a handle approximately 5 feet long (see figure 2a). Two or more men usually worked together so that as one person swept, another could hold a shovel or scoop for the sand to be brushed into and removed.

2. Corn Broom

The corn broom used was the standard model usually found in the home (see figure 2b). Decontamination was accomplished by sweeping with the broom and picking up the piles of sand and dust which resulted.

3. Vacuum Cleaner

The vacuum cleaner was a Spencer Model P-136, Large Class A, 1-1/2 hp, with two sections of hose totaling approximately 30 feet (see figure 2c). A section of pipe was fastened onto the nozzle end of the hose as a handle for the benefit of the operator. Several nozzles were tested, but one having soft-rubber padding cemented to its edges was found to be most effective. The rubber, when resting on the surface to be cleaned, created an intense vacuum. Because the

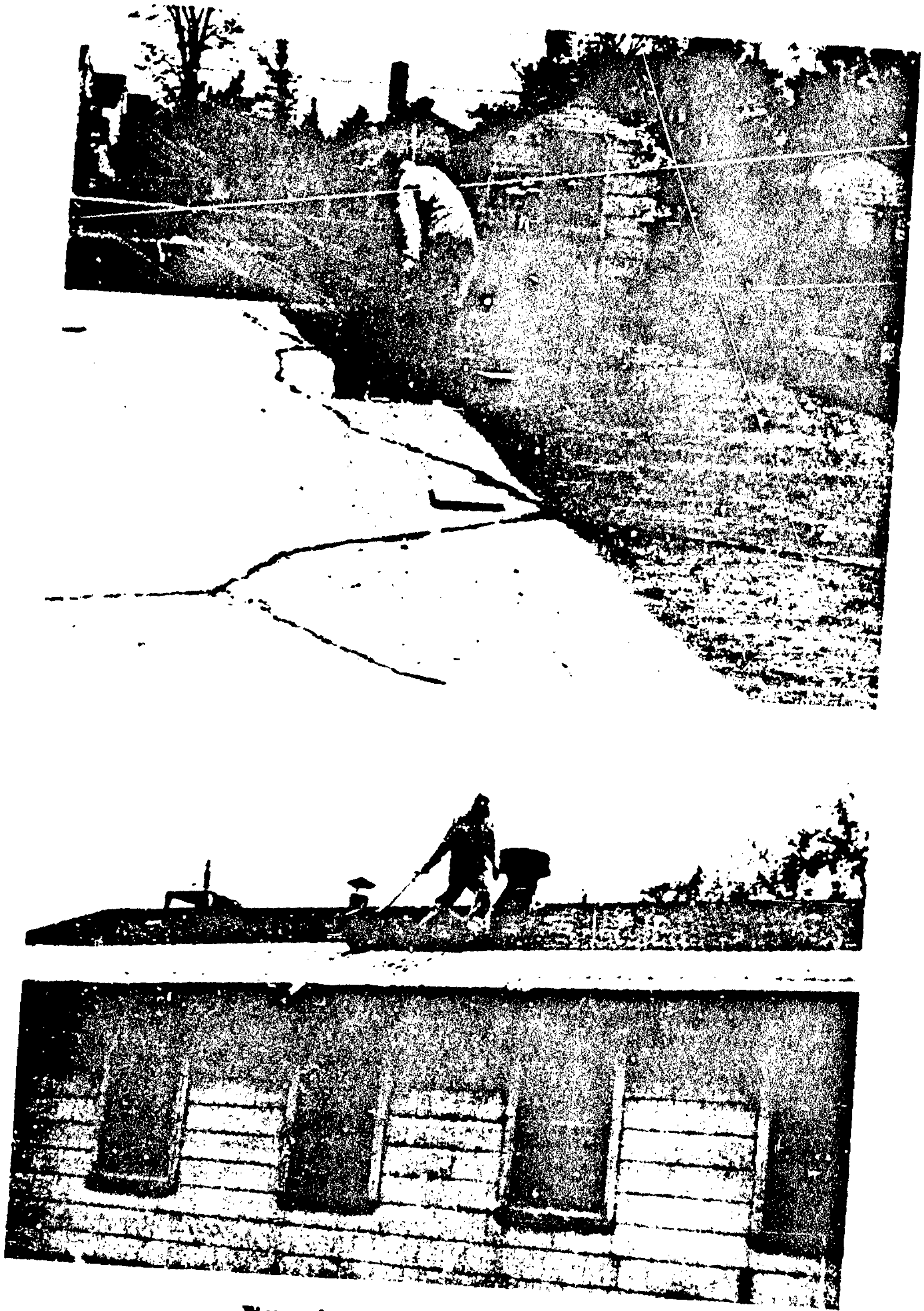

Figure 1 - Plot Contamination

container on the vacuum cleaner became radioactive very quickly, it was necessary to stay as far as possible from the tank to prevent radiation exposure. Sand collected in the tank was deposited in a metal can for storage until the radioactivity decayed to a level low enough for it to be disposed of in the normal manner.

4. Garden Hose

Water hosing was accomplished with a standard 5/8-inch-diameter hose of 50-foot sections coupled together (see figure 2d). A water meter was inserted in the line near the nozzle so that the amount of water in gallons could be measured. At this same location a tapped fitting permitted a pressure gauge to be installed. The nozzle itself was a single, brass, garden-hose nozzle that could be adjusted to provide fine, coarse, or controlled sprays on the surface to be washed.

5. Standard Lawn Mower

The standard lawn mower used (see figure 2c) was a Zephyr Model 22 with a bag attached to catch clippings from the lawn. When the bag contained enough clippings to require that it be emptied, the clippings were dumped into a metal can to be carried away. To provide the most vacuuming action, the lawn mower was operated at high speeds during decontamination procedures.

6. Toro Lawn Mower

The Toro lawn mower (see figure 2f) was operated in the same manner as the standard lawn mower. The main difference between the two was the greater suction created by the Toro.

7. Rotary Tiller

The rotary tiller (Hahn Eclipse) was an ordinary garden model of the type normally used by a home owner to plow small gardens (figure 2g). It was allowed to dig into the soil to depths from 5 to 10 inches; thus, the fallout simulant was not removed but was displaced by being plowed under (figure 3).

8. Garden Plow

The garden plow (figure 2h) was a model with a mold board plow and a turf cutter attached. The plow turned the earth in folds (see figure 4a) so that the grass and turf were completely turned under (figure 4b).

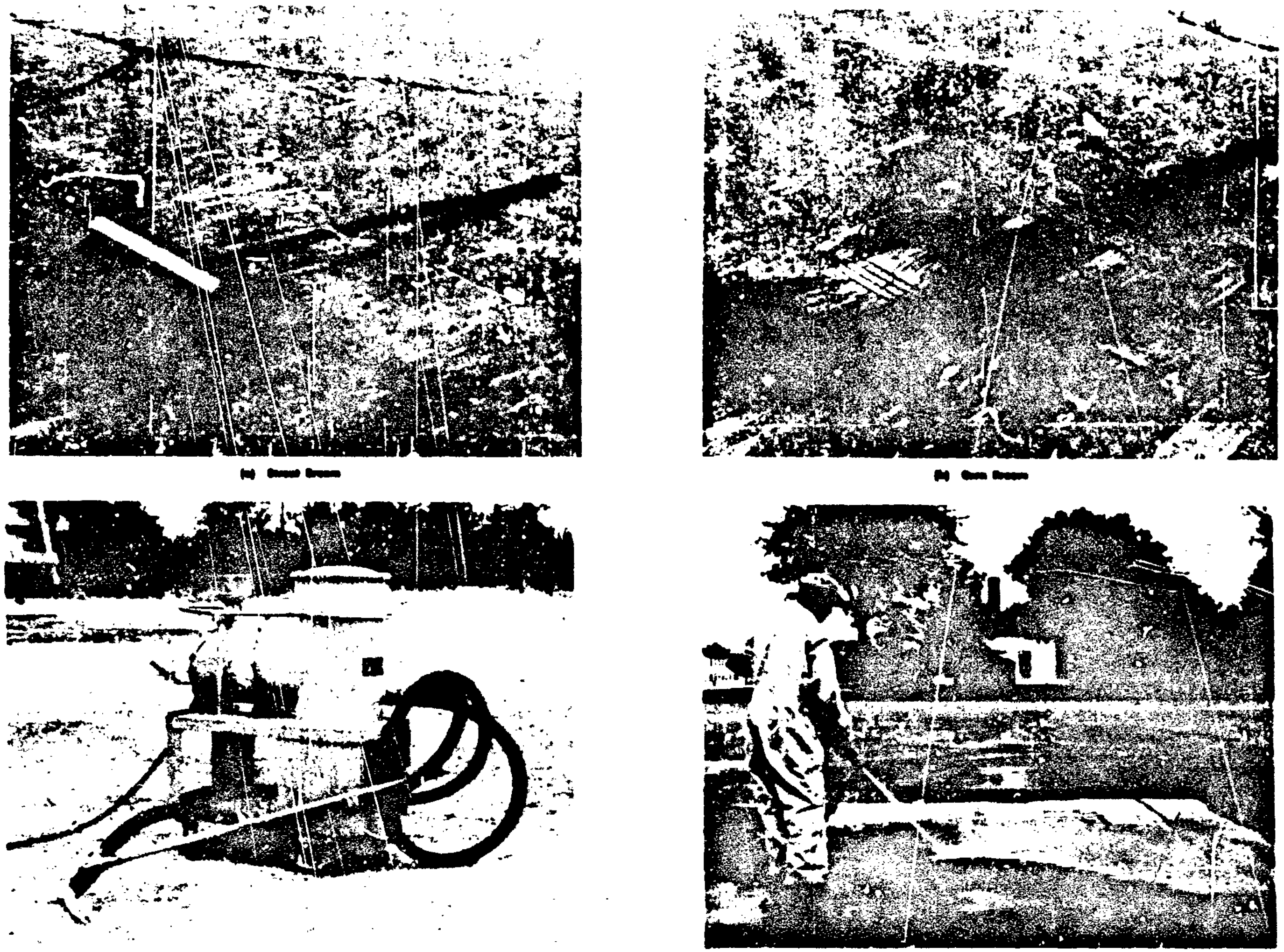

Figure 2 - Plot Decontamination Equipment

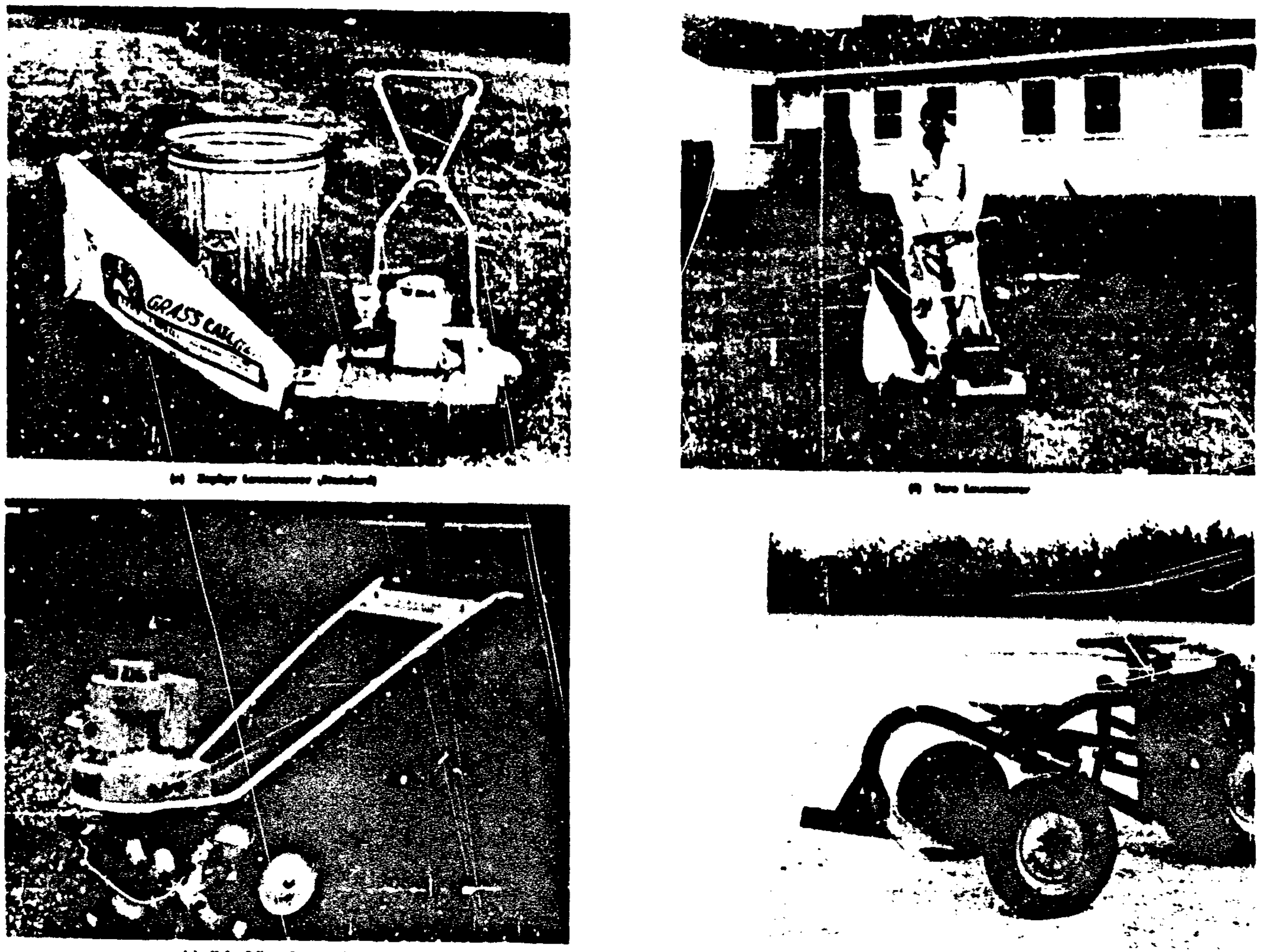

Figure 2 - Plot Decontamination Equipment

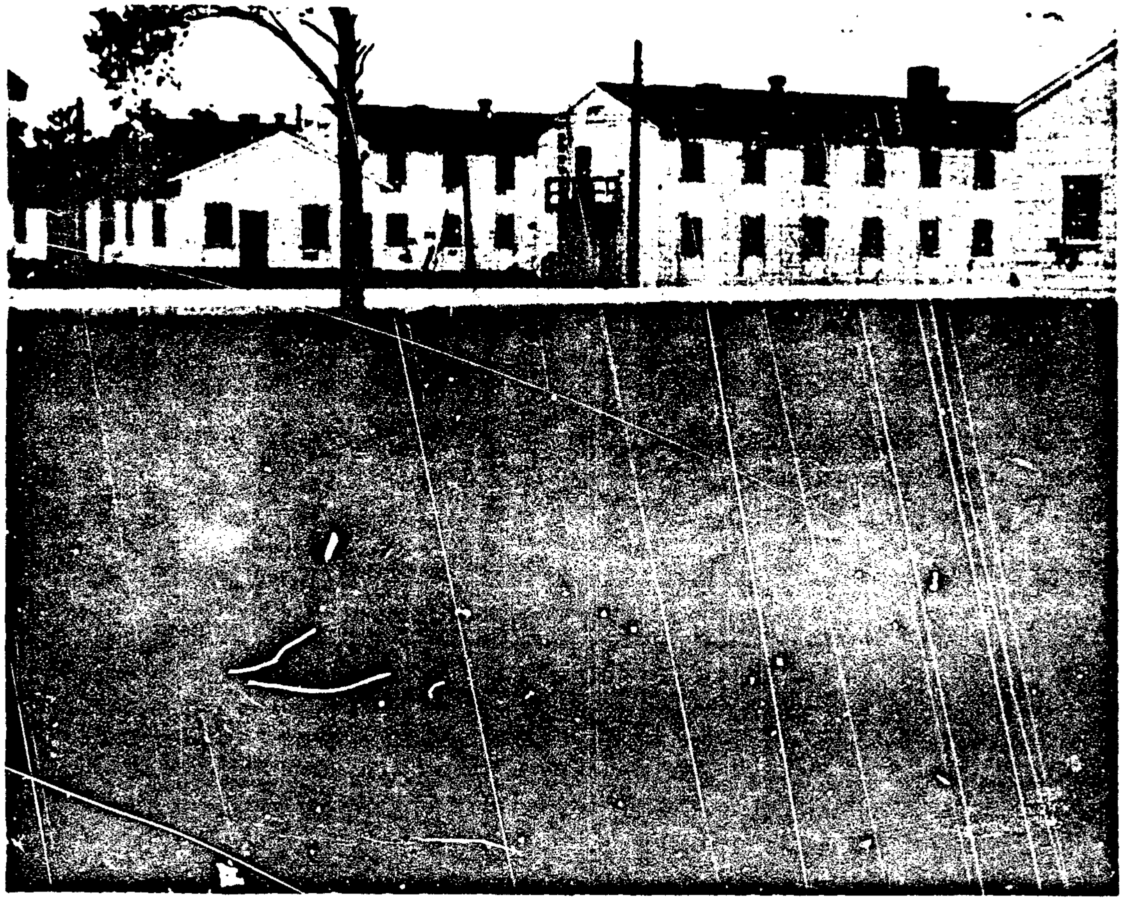

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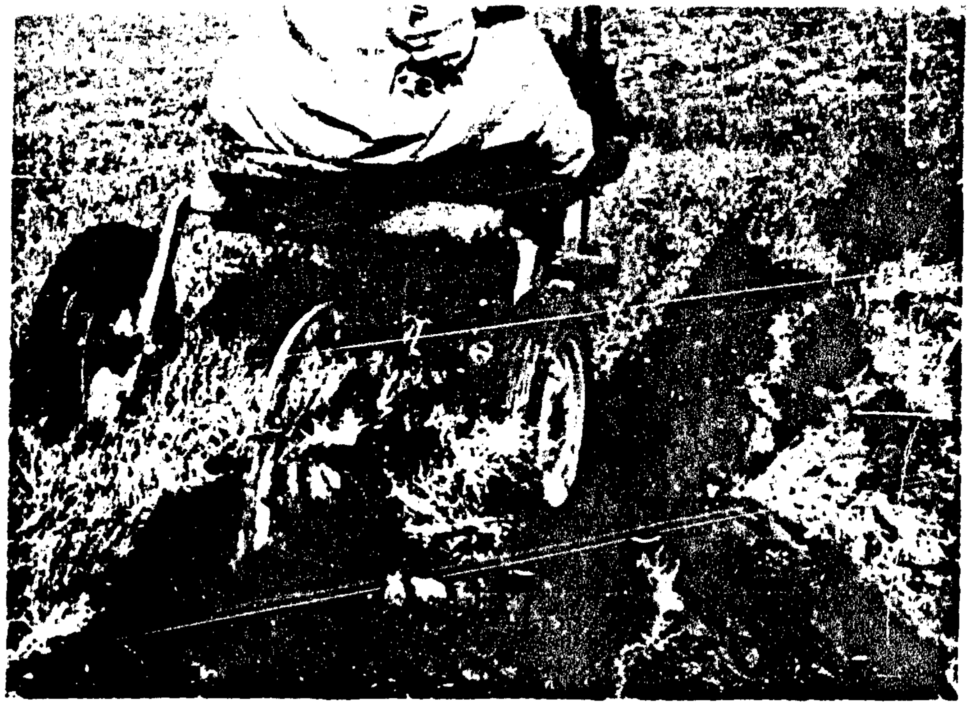
Figure 3 - Contaminated Plot After Tilling



(a) Plow in Operation

(b) Plot After Decontamination

Figure 4 - Decontamination with Garden Plow

9. Shovel

Two methods of shoveling were explored. The first involved removal of the turf, that is, the grass and about 3 inches of the earth; the turf was then placed into a wheelbarrow (see figure 5) and dumped off to the side of the plot. For the other method, the shovel was put to its full depth into the earth, and the pad of earth was picked up and turned over (see figure 6).

Decontamination operations on horizontal surfaces were conducted by making traversing passes from end-to-end of the test areas (figures 7 and 8). In the cases where sweeping and hosing operations produced ridges of removed materials (fallout-plus-loose-surface material), such ridges were shoveled into GI cans when the mass of material became noticeably more difficult to move forward. The material from soil-surface stripping operations was shoveled into wheelbarrows and piled at least 50 yards from the test area. Decontamination operations on roofs were conducted from ridge-to-eave by moving longitudinally along the roof (see figure 9).

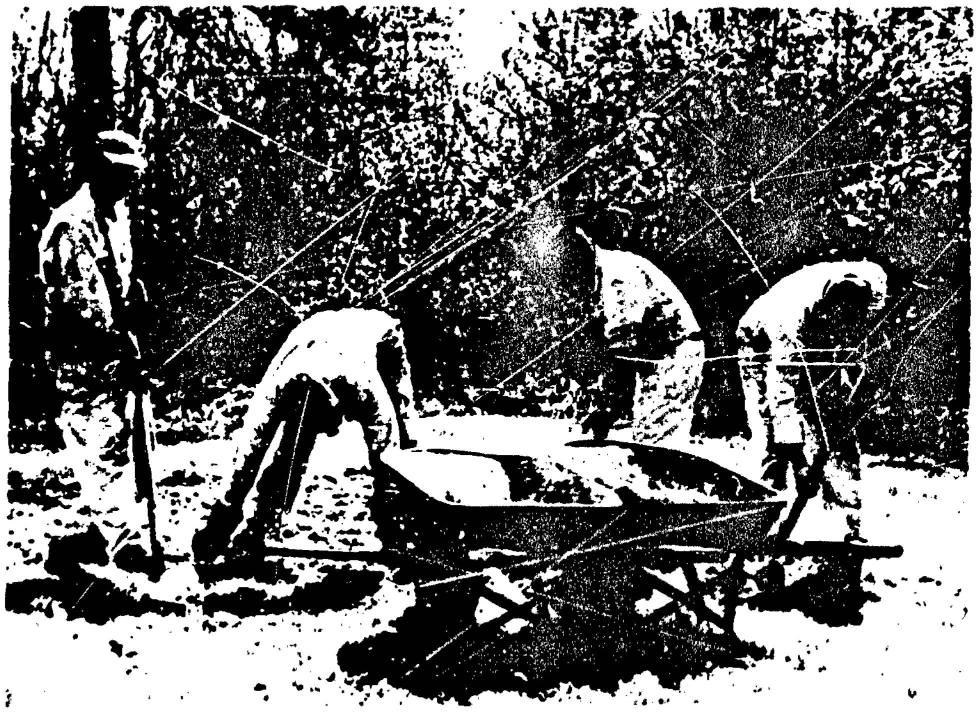
Data was obtained on mass deposit levels, required effort, operator dose rates, initial and final radiation levels, and water consumption, where applicable.

D. Radiological Instruments and Survey Procedures - Test Plots.

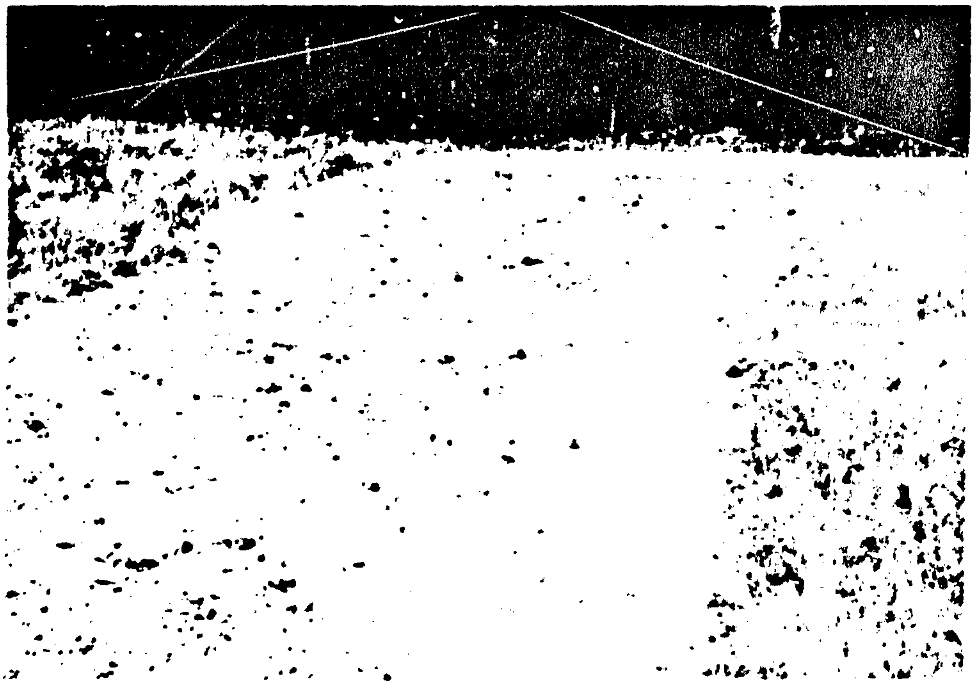
The same portable scanning apparatus that was used in the cold-weather decontamination study*, was used on all horizontal surfaces. This was a wheeled truss with a 20-foot clear span that straddled the test plot (see figure 10). A collimated anthracene scintillation crystal with a photomultiplier tube was suspended from the truss on rollers so that the crystal was 1 foot above the surface. An endless cable and crank enabled the operator to traverse the detector from one side of the plot to the other. A linear potentiometer was coupled to the crank. The outputs from the detector head and the potentiometer were fed by cable to an instrument rack and to an X-Y recorder where the amplified detector output versus detector position was plotted. Traverses or "scans" were made at 10-foot intervals or less, along each test plot. Scans were made before and after decontamination at the same positions over the plots.

For some test plots, readings were taken 3 feet above the surface at the starting end of the plots with a "cutie-pie". Readings were taken at this point as the decontamination effort progressed down the plot.

Readings were taken at selected points on the roofs with the collimated detector head from the traversing mechanism positioned 1 foot above the surface (see figure 11).



(a) Removing Turf



(b) Plot After Decontamination

Figure 5 - Decontamination by Shovel Scraping

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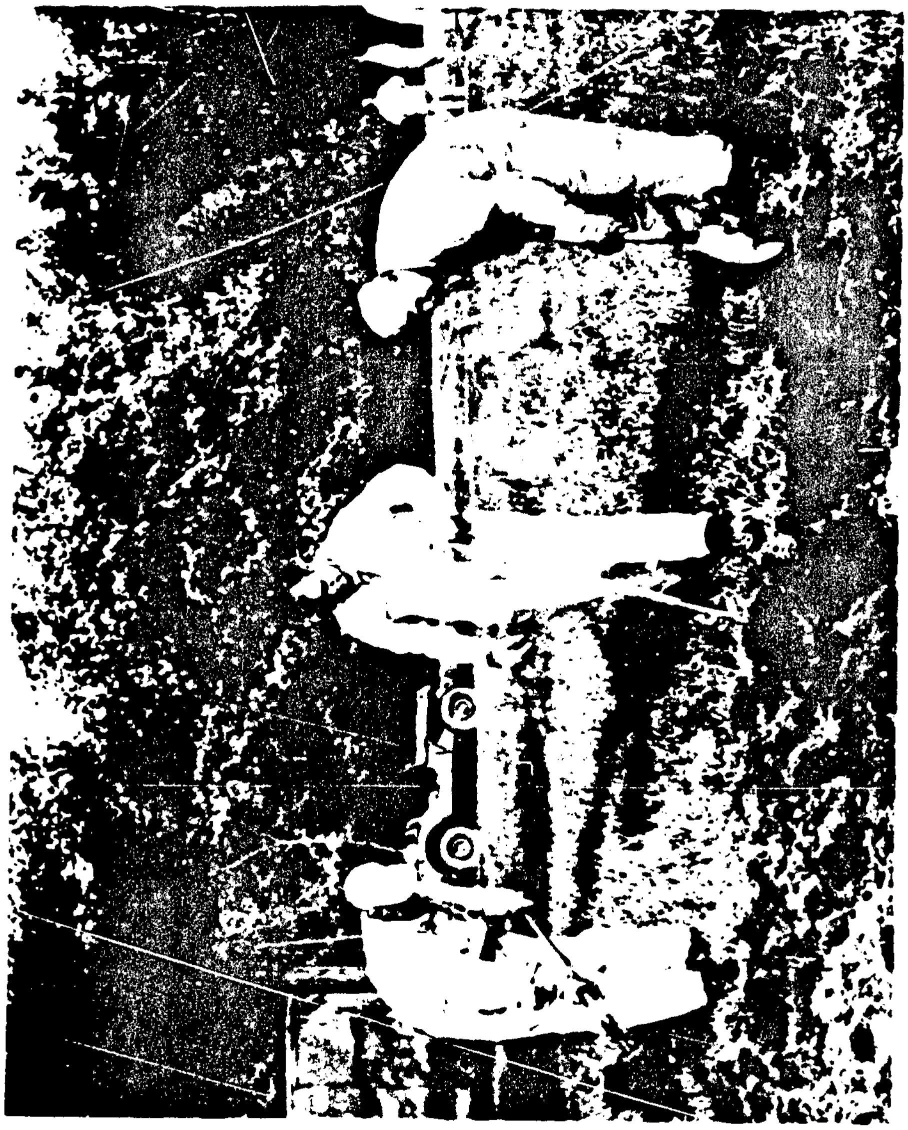

Figure 6 - Decontamination by Shovel Spading

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Figure 6 - Decontamination by Shovel Spading

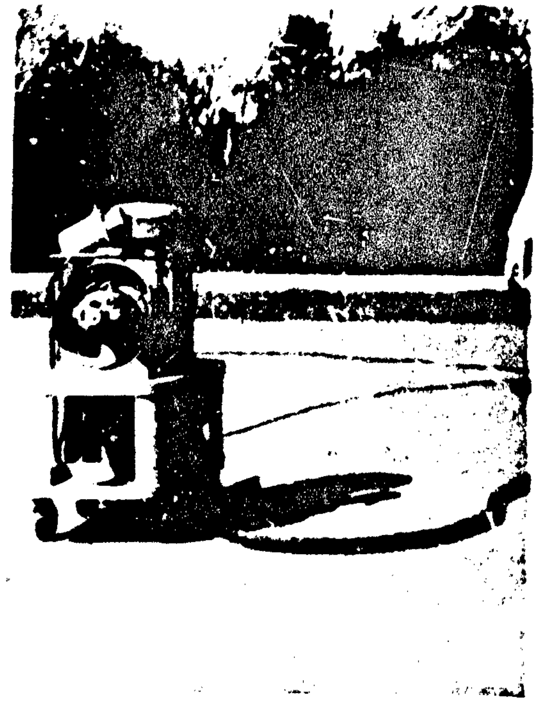


Figure 7 - Vacuum Cl

Figure 8 - Vacuum Clea

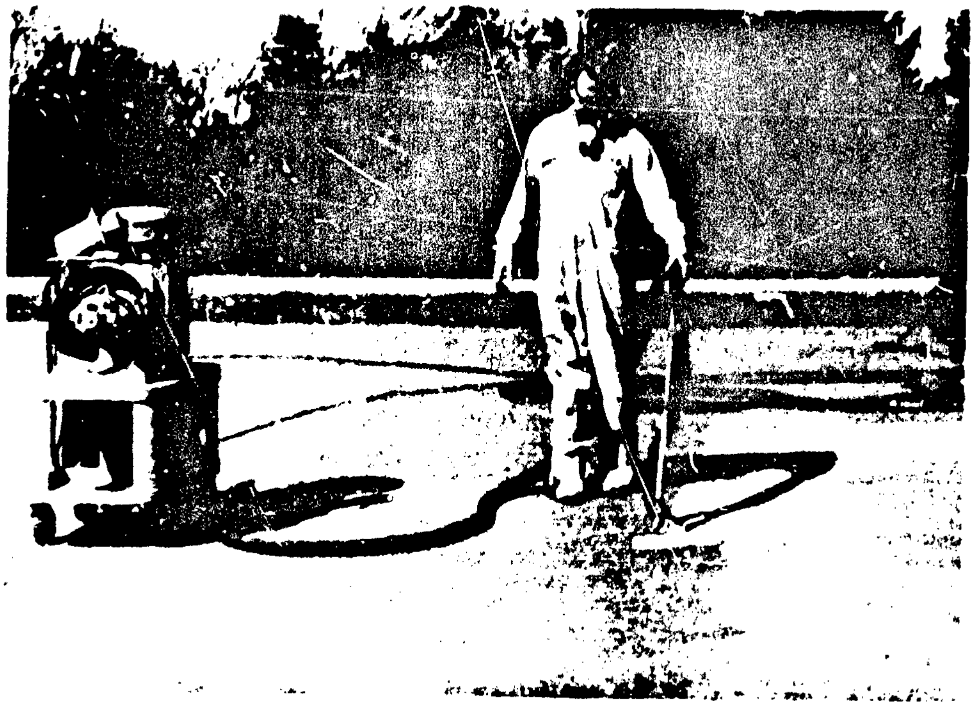


Figure 7 - Vacuum Cleaning Asphalt Plot

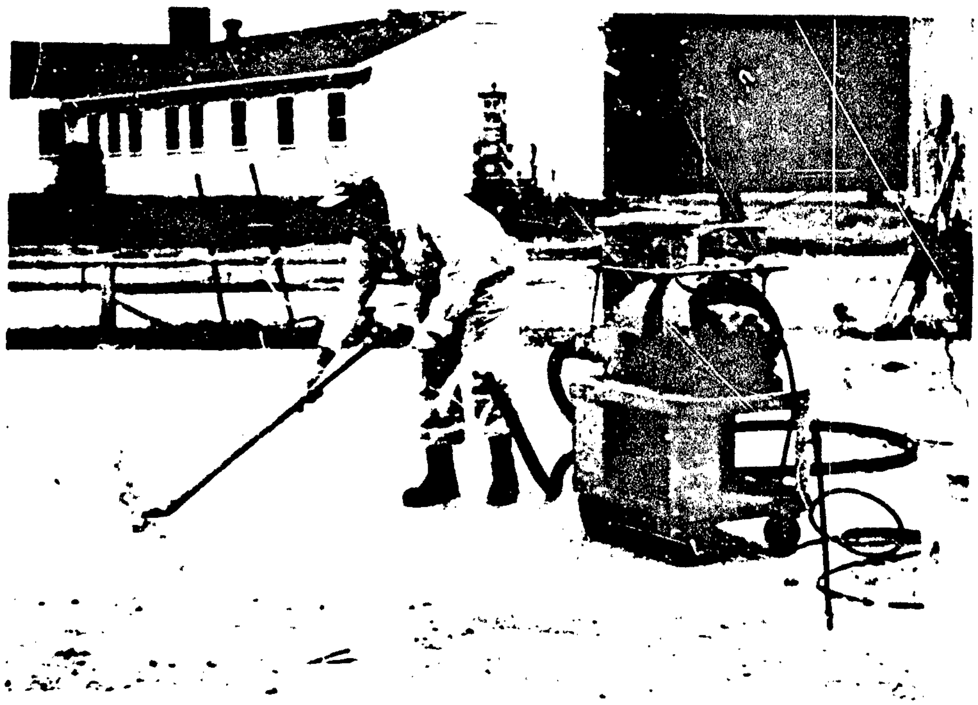
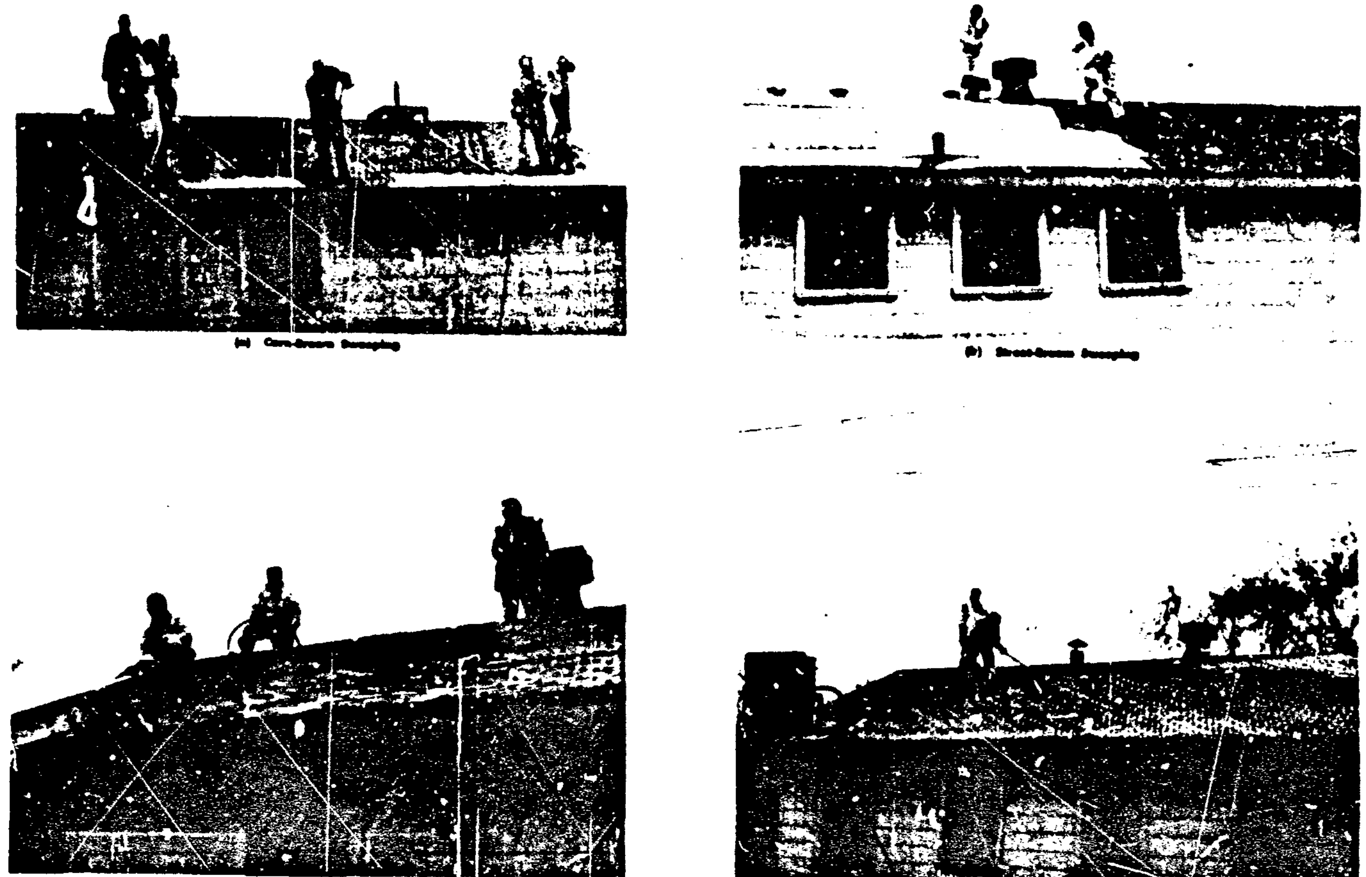


Figure 8 - Vacuum Cleaning Concrete Plot



(a) Corn-Broom Sweeping

(b) Street-Broom Sweeping

(c) Water-Hosing

(d) Vacuum-Cleaning

Figure 9 - Roof-Decontamination Methods

Figure 10 - Ground Plot Scanning (Automatic Detection System)

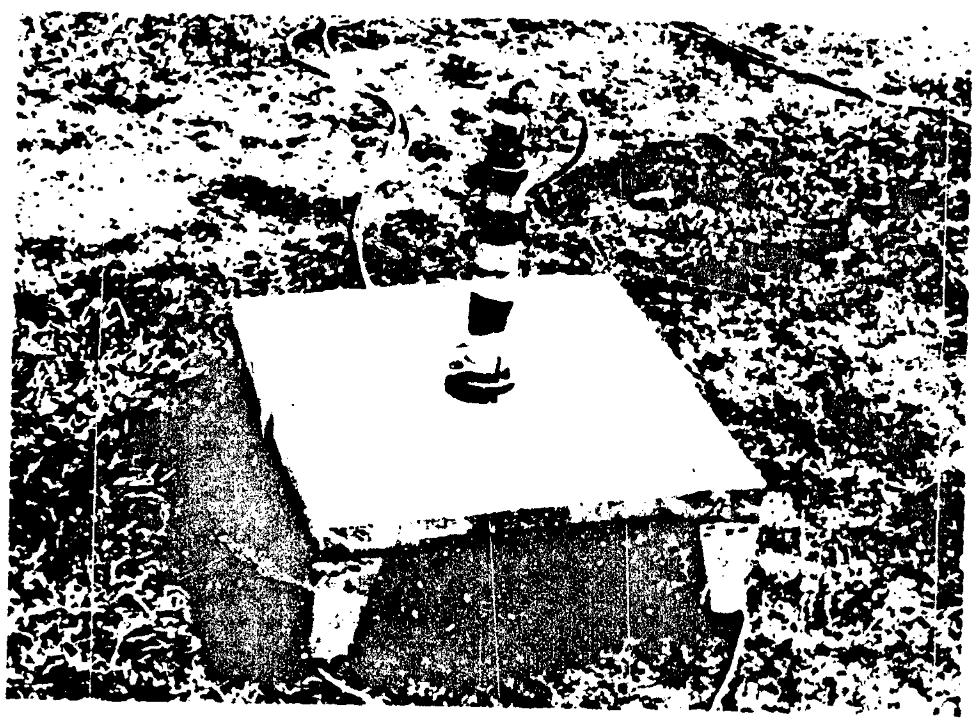


Figure 11 - Detector on Roof-Scanning Dolly

E. Radiological Operations - Residential Area.

The residential structure is shown in figure 12, and its interior floor plan in figure 13. This small, furnished, frame residence was a regimental commander's quarters. Contamination operations were performed in the following sequence:

1. Contaminate roof of structure.

2. Radiological survey of building interior.

3. Contaminate a 10-foot wide area around the structure.

4. Radiological survey of building interior.

5. Contaminate another 10-foot wide area around the structure (20 feet).

6. Radiological survey of building interior.

7. Contaminate another 10-foot wide area around the structure (30 feet).

8. Radiological survey of building interior, roof, and land areas (see figure 14).

The plan was to contaminate the ground to a distance of 50 feet from the structure; however, the inside readings leveled off after contaminating to 20 feet, and spreading of contamination was discontinued at 30 feet.

The following decontamination and survey operations were then performed. The choice of decontamination techniques was based on preliminary results from the decontamination of test plots.

1. Hose roof with garden hose at 35 psi.

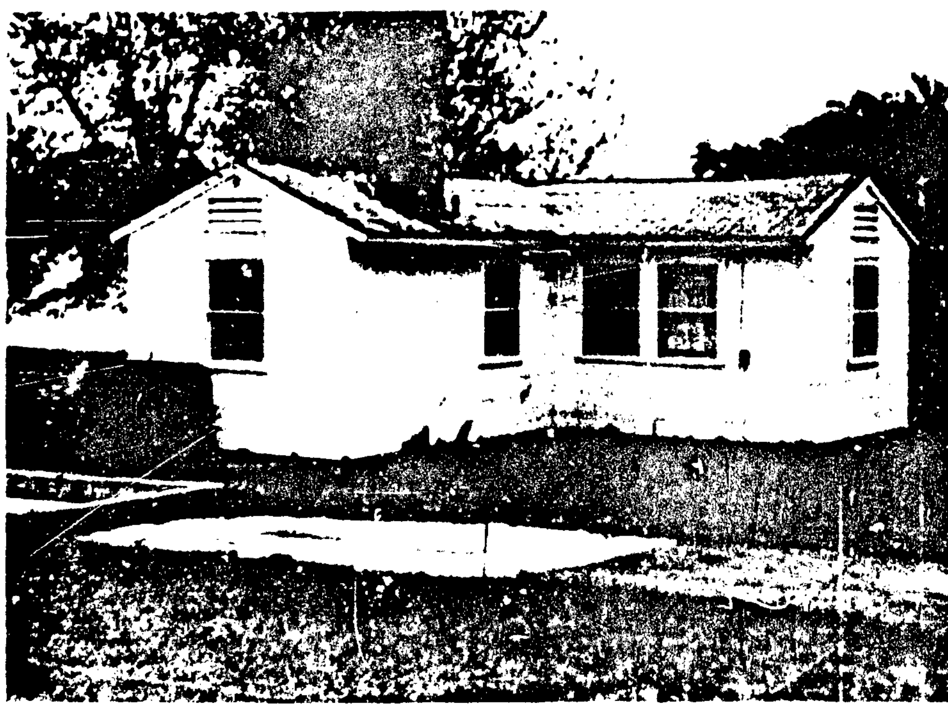
2. Survey structure interior and roof.

3. Scrape surface layer of soil with a shovel in 10-foot wide zone around structure. Remove spoil to a pile 50 yards from area (see figure 15).

4. Survey structure interior.

5. Plow remaining soil areas and corn-broom sweep all sidewalks, driveway, and coal bin areas (see figures 16 and 17).

(a) Before Contamination



(b) After Contamination

Figure 12 - Complex Area

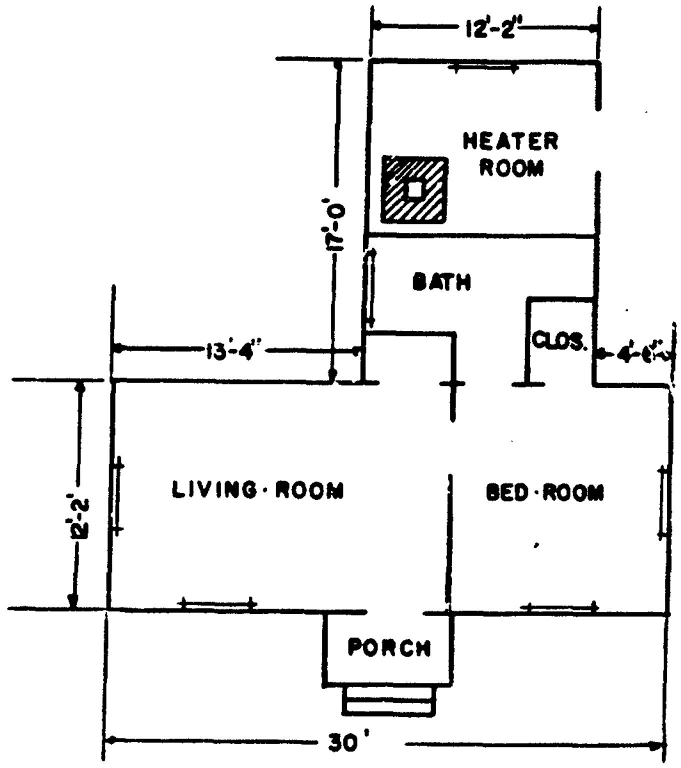


Figure 13 - Typical Floor Plan, RCQ-1

Figure 14 - Radiation Measurements on Roof of Complex Building

Figure 15 - Shovel Scraping of Complex Area

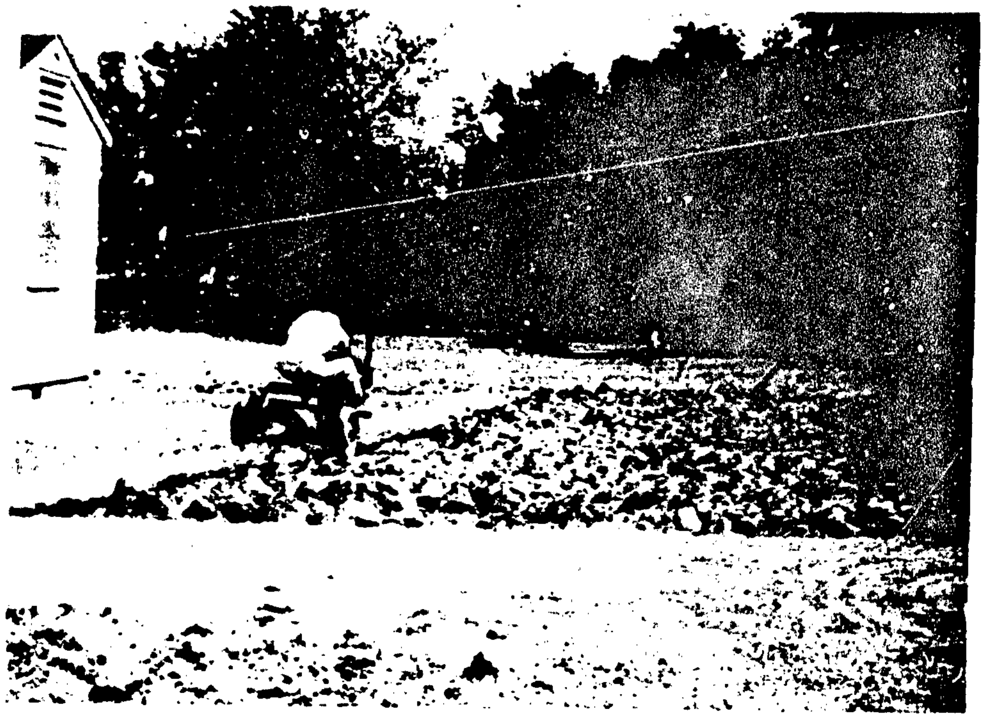


Figure 16 - Plowing the Complex Area

Figure 17 - Complex Area after Decontamination

TABLE 3

RESULTS OF DECONTAMINATION OF RESIDENTIAL STRUCTURE AND LAWN

Location inside structure	Ratios of radiation levels to initial central area radiation level			
	Area contamination	Roof decontamination	Decontamination at 10 ft	Decontamination at 30 ft
Central area	1.00	0.68	0.32	0.15
Along walls	1.17	1.00	.37	.17
Corners	1.40	1.45	.46	.18
Effort $\frac{\text{man-hours}}{1000\ ft^2}$		0.28	11.77	0.74
Effort for task, man-hours		0.23 (837 ft^2)	17.37 (1476 ft^2)	3.77 (5088 ft^2)
Estimated dose for task 2 weeks after event (2000 r/hr at H+1 hr)		0.2r	22.3r	5.6r

TABLE 4

RESULTS OF SPECIAL DECONTAMINATION TESTS

Surface	Method of decontamination	Activity remaining	Effort
		%	$\frac{\text{man-hr}}{1000\ ft^2}$
Macadam pavement	Street broom sweep	84.9 ± 0.9	0.1
		63.5 ± 7.5	0.2
		55.4 ± 3.8	0.3
		47.2 ± 5.2	0.4
Asphalt pavement	Garden hose, 35 psi	36.7 ± 4.1	0.3
		10.7 ± 3.2	0.7
		5.6 ± 0.4	1.0
		5.2 ± 0.4	1.3

B. DISCUSSION.

The decontamination of test plots was conducted on areas from 10 to 20 feet wide and from 40 to 100 feet long. Contamination of the test plots, averaged over the entire series, was 47.9 gm/ft² at 18.6 μc/gm. The collimated detecting element, located 1 foot above the surface, received about 40 mr/hr of radiation. With 99% decontamination, the radiation level in the detector element is 0.4 mr/hr, which is well above its minimum sensitivity to discriminate background radiation and electronic noise. The radiation intensity measurements were taken, for the most part, as scans across the test plot. The resulting value of each scan could, therefore, be considered as an average value of radiation intensity. This greatly enhanced the results of the data analyses, as it reduced the confidence intervals about the average percentage of activity remaining. This approach could not be used where point measurements were taken, i.e., roofs, which resulted in larger confidence intervals.

The results of the decontamination of test plots reflect only the reduction of radiation levels that were directly over the decontaminated area. Just as important is the reduction of radiation intensity that can be effected by decontamination of adjacent areas. Additional data, recorded during several of the tests, could be used to determine radiation contribution from adjacent areas. These data were obtained by taking radiation intensity measurements at one end of the test plot with a "cutie-pie" as decontamination progressed down the test area. These data do not have as inherent precision as do the data taken over the plot due to instrumentation and number of measurements. Much more sophisticated techniques and instrumentation would be required to obtain data that would accurately describe the effect of adjacent area decontamination; nevertheless, the field data obtained can be used to great advantage for checking the validity of a mathematical model derived for this purpose, and sufficient agreement between the field data and the model enables projection of the model to larger areas. Such projection is not always feasible in field tests.

The experimental data and calculated values are given in table 5. Measurements were taken at a height of 3 feet at the midpoint of one end of the test plot, and were recorded as the decontamination progressed from the measurement point. They are reported as percentages of the measurement taken before decontamination began. The mathematical model was designed[4], using the test plot dimensions and the activity-remaining percentage of each individual test in order to compare data.

TABLE 5

COMPARISON OF EXPERIMENTAL AND MATHEMATICAL DECONTAMINATION EFFECT OF ADJACENT AREAS

Description of test	Length of area decontaminated	Radiation level at end of plot		
		Experimental	Model	Model corrected for shielding
	ft			
Asphalt decontaminated by street broom (20x100 ft)	0	100	100	
	10	35	39	
	20	24	27	
	30	21	22	
	40	19	20	
	50	19	19	
	60	19	18	
	70	18	17	
	80	18	17	
	90	17	16	
	100	17	15	
Loam decontaminated by Roto-tiller (20x100 ft)	0	100	100	
	10	83	82	
	20	80	79	
	30	80	77	
	40	80	77	
	50	80	76	
Concrete decontaminated by corn broom (20x60 ft)	0	100	100	
	10	30	28	
	20	20	15	
	30	14	9	
	40	13	7	
	50	9	5	
	60	7	4	
Loam decontaminated by shovel scrape (10x100 ft)	0	100	100	
	5	64	47	
	10	34	31	
	15	24	24	
	20	24	21	
	25	24	18	
	30	24	17	
Loam decontaminated by spading (10x100 ft)	0	100	100	100
	5	57	65	61
	10	47	55	50
	15	45	50	45
	20	43	48	42
	25	40	46	40
	30	38	46	40
	40	38	44	38
	50	38	44	37
	60	36	43	37
Loam decontaminated by garden plow (20x100 ft)	0	100	100	100
	5	42	76	60
	10	42	67	46
	15	42	63	39
	20	42	61	35
Asphalt decontaminated by corn broom (20x100 ft)	0	100	100	
	10	33	34	
	20	28	21	
	30	25	16	
	40	23	14	
	50	23	12	
	60	22	11	

Comparison of the experimental and calculated radiation levels at the end of a test plot generally agree within a few percent. Notable exceptions are spading and use of the garden plow. These were anticipated, as the shielding geometry of the turned-over earth directly over the plot differed from that at the side. The shielding factor of the spading was approximately 0.9; of the garden plow, approximately 0.6. A similar shielding factor would be expected from the rototilling experiment; its absence is probably due to the mathematical model's lack of fit when the percentage of decontamination is very low.

Another important factor that can be evaluated from the field data is the operator dose rate. A reasonably accurate estimate of the expected dose rate can then be coupled with the required effort for a particular decontamination task; this would give the dose the operator would be expected to receive. Because the operator dose is the crux of any decontamination operation planning, data pertaining to operator dose rates were taken.

It is obvious that the dose rate experienced by decontamination operators will vary widely during the operation. At the start, the dose rate will be the field intensity. As decontamination proceeds over an appreciable area, dose-rate contribution from the decontaminated area will drop in proportion to decontamination effectiveness; however, the operator's total dose rate will depend upon what is being done with the contaminant. In sweeping or hosing operations, the contaminant is concentrated in front of the operator; this greatly increases his dose rate. When the contaminant is buried, as in plowing or spading, the operator has the advantage of the shielding afforded by the earth. In removal operations, such as shovel scraping, the contaminant is removed from the vicinity and will not contribute to the localized dose rate, but where the contaminant is collected, such as in a vacuum cleaner, a very intense field is generated near the machine.

After the initial stages of decontamination by burial, removal, and collection techniques had been performed, the operator dose rate was approximately 60% of the original field intensity. In the hosing and sweeping operations, the operator dose rate increased by 25% to 50% for each 10 feet of decontamination progress. The dose rate would continue to build up unless the accumulated contaminant was removed periodically. Such removal was necessary, however, because the accumulation became too bulky to be effectively manipulated. It became evident that contaminant removal was necessary for every 10 to 15 feet of travel when hosing, and every 40 to 50 feet of travel when sweeping.

The various methods to decontaminate a particular surface in a uniform fallout field can best be compared on the basis of dose incurred and benefits received from a given task. Estimates of dose and reduction of dose rate were made for 20- by 50-foot plots in an open field and for plots adjacent to a building, and are presented in table 6 for each of the various surfaces and methods. It is not intended that the values be used as basic parameters for decontamination-operation planning of dose and dose rates; more refined calculation would be necessary; however, the accuracy is sufficient for comparison of methods. The values given in the table are ratios of the initial dose rate (r/hr) at a height of 3 feet taken at (1) the center of the decontaminated plot in the infinite 1 r/hr open field and at (2) the midpoint of the 50-foot dimension edge of the decontaminated areas adjacent to a building. Minimum values for dose rate remaining with 100% decontamination for the two hypothetical situations are 0.52 r/hr and 0.20 r/hr, respectively.

The residential complex test consisted of contaminating the roof of a quarters-type building (T-shaped with 560 square feet of floor area) and of contaminating a distance of the surrounding lawn to 30 feet from the building. The roof was contaminated to a radiation intensity of about 100 mr/hr at 3 feet above the roof, which resulted in a 27 mr/hr level inside the building at 3 feet above the floor level. The surrounding lawn was then contaminated to a 140 mr/hr intensity at 3 feet, which increased the level inside the building to an average of 73 mr/hr. The overall contribution to the building's radiation level from the roof contamination was about 37%. However, in the central portion of the room, 6 feet from walls, where the radiation level is the lowest when roof and ground are contaminated, the contribution from the roof was 50%. The expected 80% to 90% decontamination of the roof would mean a radiation level reduction in the center of the room to about 60%. The experimental result of 63% is due to the increase of contaminant immediately around the periphery of the building because of roof washdown.

An estimate follows of the shielding afforded by the simple frame structure to the central portion of the room, expressed as percentages of the outside infinite field dose rate. This is based on experimental data plus calculations to adjust to an infinite contaminated field.

Infinite field dose rate at 3 feet	100%
Inside building, 3 feet above floor, no decontamination	40%
Inside building, roof decontaminated	30%

TABLE 6

ESTIMATED DOSE AND EFFECTIVENESS FOR DECONTAMINATION OF 20-BY 50-FOOT PLOTS IN 1 R/HR INFINITE FALLOUT FIELD

Surface	Decontamination method	Open field		Field adjacent to bldg	
		Dose to operator	Dose rate remaining	Dose to operator	Dose rate remaining
		r	r/hr	r	r/hr
Macadam	Street broom	2.0	0.89	2.0	.43
	Corn broom	2.4	.62	2.4	.27
	Vacuum cleaner	1.4	.53	1.3	.21
	Garden hose	2.4	.53	2.4	.21
Asphalt	Street broom	1.0	.60	1.0	.25
	Corn broom	1.2	.57	1.2	.23
	Vacuum cleaner	0.9	.53	0.8	.21
	Garden hose	3.0	.54	3.0	.21
Concrete	Street broom	1.2	.55	1.2	.22
	Corn broom	1.0	.54	1.0	.21
	Vacuum cleaner	0.6	.53	0.6	.21
	Garden hose	1.2	.53	1.2	.21
Grassy Loam	Lawn mower	0.6	.95	0.6	.47
	Vacuum cleaner	1.8	.92	1.7	.45
	Shovel scrape	10.3	.58	9.9	.24
	Rototill	0.9	.88	0.9	.43
	Spade	9.5	.69	9.3	.30
	Garden plow	0.5	.64	0.5	.27
Any	A 100% effective method		.52		.20

Inside building, roof and 10 feet decontaminated	15%
Inside building, roof and 30 foot area decontaminated	6%

The data from special tests, relating effort and effectiveness of decontamination, were obtained by street broom sweeping a 20- by 40-foot macadam road as rapidly as possible four times, and from water hosing four different 10- by 15-foot asphalt plots at prespecified time limits. The results have been presented in table 4. This data, plotted on semilogarithmic graph paper (see figures 18 and 19) illustrate the correlation between the data and the equation.

$$C = C' + (C_o - C') \exp(-KE) \qquad (1)^*$$

where

C = contamination percentage remaining after a level of effort is expended

C_o = initial contamination level (100%)

C' = residual contamination percentage at an infinite effort level

E = effort (man-hours/1000 ft^2)

K = effort efficiency constant

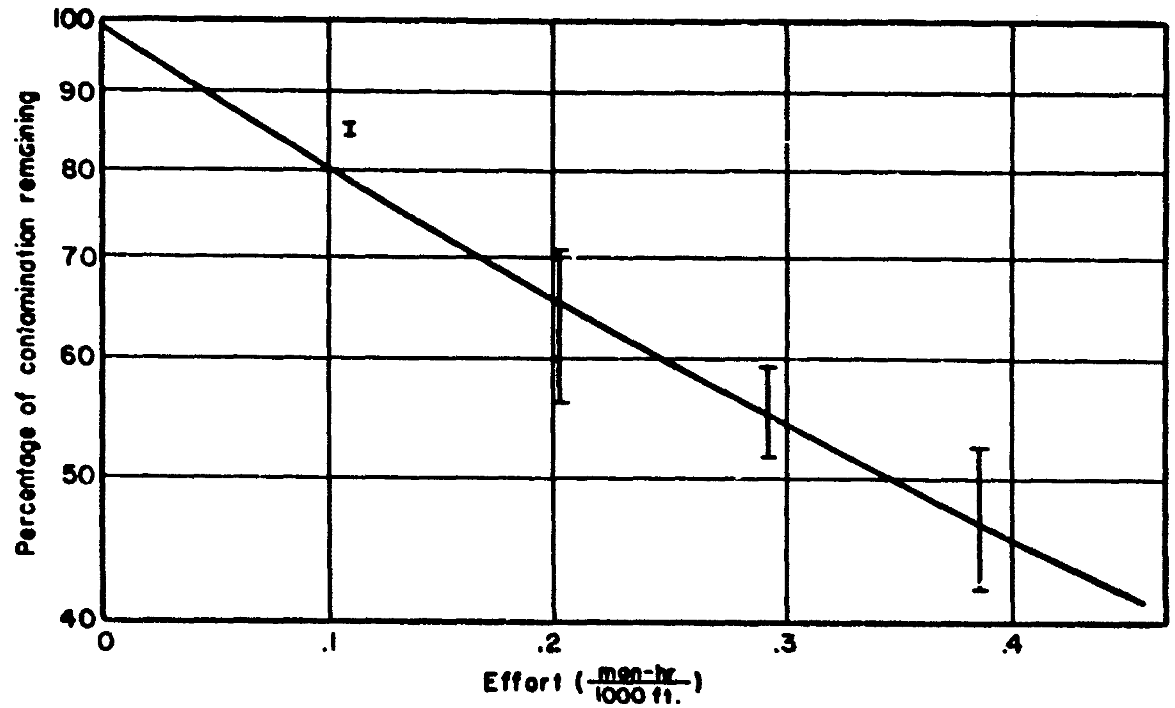
* Equation (1) was adapted from USNRDL-TR-336, reference 5.

C. CONCLUSIONS.

1. Simple decontamination methods such as sweeping, vacuum cleaning, and garden hosing are effective when applied to roofs and paved areas. Their application will be limited by the operator dose received during the low output work period.

2. Surface removal is the only effective simple method applicable to soil. Work rates are very low and will vary according to the soil condition. However, plowing with a garden tractor is applicable to adjacent areas or buffer zones.

3. Effective radiological recovery of a small residence and lawn can be accomplished in a heavy fallout area, 2000 r/hr at H+1 hr, after a two-week waiting period, with a one-man decontamination crew receiving a dose of approximately 25r.



NOTE:

Curve based on equation

$C = C^{\circ} + (C_{o} - C^{\circ})e^{-KE}$

$C = 20 + (100-20)e^{-2.8E}$

Figure 18 - Effectiveness of Street Broom Sweeping on Macadam

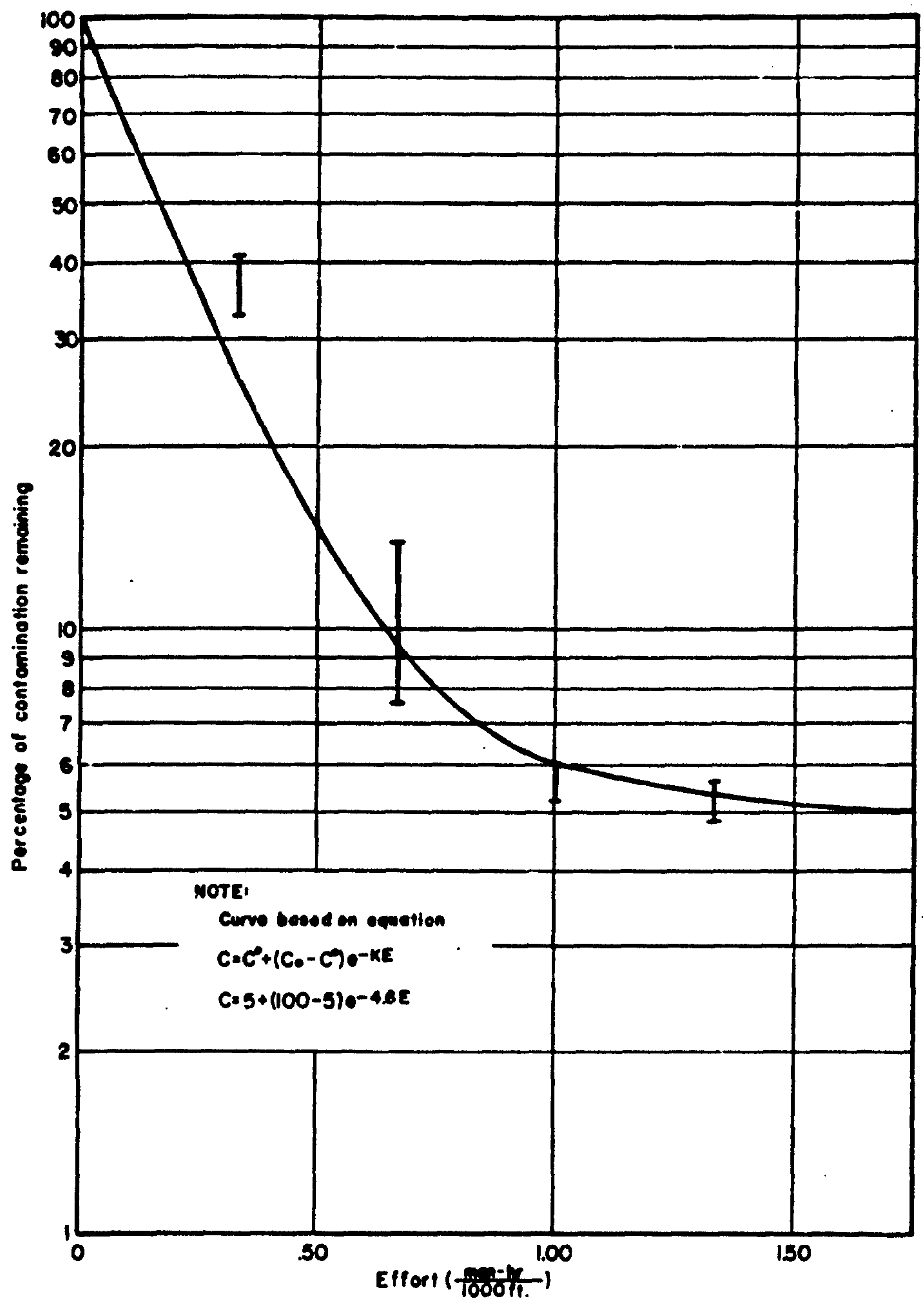


Figure 19 - Effectiveness of Garden Hosing on Asphalt

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APPENDIXES

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APPENDIX A

EXPERIMENTAL DATA FROM TEST PLOTS

I. DESCRIPTION OF DATA.

The data collected from the field tests of plots consist of (1) radiation measurements taken at a height of 1 foot above the surface before and after decontamination, (2) mass level and specific activity of the fallout simulant collected in sample pans, (3) decontamination time and number of operators, (4) operator dose rate, and (5) any other pertinent data for particular tests (water consumption, weight of contaminant removal, etc.)

II. TABULATION OF DATA.

The data collected from the field tests are presented in tabular form for each test and are grouped by type of surface. The radiation level values and the simulant specific activity have been corrected for decay to the time of contamination. Averages are given with standard deviations. The units used for activity level correspond approximately to 6.67 mr/hr per unit value. These units (R) are experimentally related to the activity level (A mc/ft^2) of the contaminant on the test plot by the equation:

$$A \approx 0.014 \ R$$

TABLE A-1

TEST-PLOT DECONTAMINATION DATA

9 May 1962

EQUIPMENT Rotary Tiller

Temperature (°F)
Air 45 Surface 46
Median Time of:
Contamination 0958
Decontamination 1141
Time to Decontaminate 104 min

SURFACE Turf-Covered Sandy Loam (20' x 100')
Contamination Level 17.7 ±1.4 μc/gm
Deposition Level 54.8 ±7.5 gm/ft²
Activity Level 0.97 mc/ft²
Dose Rate to Operator 65 mr/hr
Effort 0.87 man-hours/1000 ft²
Number of Operators 1 man

Distance from end (ft)	Contamination radiation level*	Decontamination rudiation level*	Activity remaining (%)
5	51.06	39.76	77.9
10	56.85	44.98	79.1
20	62.60	47.61	76.0
30	55.71	36.48	65.5
40	57.63	4[illegible].02	76.4
50	59.68	46.05	77.2
60	55.60	49.87	89.7
70	59.19	40.78	68.9
80	57.20	38.86	67.9
90	59.17	42.46	71.7
95	54.24	43.24	79.7
AVERAGE	57.18 ±0.93		75.5±2.0

* Values are proportional to the amount of contamination

REMARKS:
1. The surface was covered with grass about 5 inches high. Ground was moist.
2. A portion of the plot was slowly and carefully plowed to a depth of 10 inches. The rest was plowed to between 5 and 7 inches. No difference in activity level was detected by the scanner.
3. Relative humidity was 77%.

TABLE A-2

TEST-PLOT DECONTAMINATION DATA

18 May 1962

EQUIPMENT Garden Plow

Temperature (°F)
Air 87 Surface 90
Median Time of:
Contamination 0745
Decontamination 1847
Time to Decontaminate 70 min

SURFACE Turf-Covered Sandy Loam (20' x 100')
Contamination Level 15.8 ±0.4 μc/gm
Deposition Level 54.9 ±5.3 gm/ft²
Activity Level 0.87 mc/ft²
Dose Rate to Operator 60 mr/hr
Effort 0.58 man-hours/1000 ft²
Number of Operators 1 man

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	32.65	17.96	55.0
10	34.92	19.86	56.9
20	31.87	15.31	48.0
30	40.78	19.21	47.1
40	44.27	22.51	50.8
50	46.13	25.40	55.1
60	46.29	27.72	59.9
70	46.65	27.83	59.7
80	44.34	28.54	64.4
90	43.41	23.48	54.1
95	41.57	23.23	55.9
AVERAGE	41.27 ±1.66		55.2 ±1.6

* Values are proportional to the amount of contamination

REMARKS:
1. The contaminant was unevenly spread over the plot because of bumpy ground and tall grass (8 inches).
2. The furrow was from 4 to 6 inches deep.
3. The plow broke down several times, requiring 9 hours for repair.
4. Actual decon time was 1 hr 10 min.
5. Relative humidity was 70%.

TABLE A-3

TEST-PLOT DECONTAMINATION DATA

16 May 1962

EQUIPMENT Shovel (Scrape) SURFACE Turf-Covered Sandy Loam (45' x 10')

Temperature (°F)
Air 88 Surface 94
Median Time of:
Contamination 0941
Decontamination 1449
Time to Decontaminate 152 min

Contamination Level 33.2 ±1.1 μc/gm
Deposition Level 47.8 ±1.9 gm/ft²
Activity Level 1.59 mc/ft²
Dose Rate to Operator 54 mr/hr
Effort 28.12 man-hours/1000 ft²
Number of Operators 5

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	50.19	6.81	13.6
10	50.19	6.38	12.7
20	53.88	5 80	10.8
30	51.45	5.06	9.8
40	49.47	6.31	12.7
AVERAGE	51.04 ±0 78		11.9 ±0.7

* Values are proportional to the amount of contamination

REMARKS:
1. The "sandy loam" surface was a turf-covered, gravel parking lot. The gravel, about 1-1/2 inches below the surface, caused difficulty in the decontamination. The time expended was not representative of a sandy-loam surface. A similar method used in complex test required 11.77 man-hours/1000 ft².
2. Rest periods are excluded from the decon time.
3. Relative humidity was 64%.

TABLE A-4

TEST-PLOT DECONTAMINATION DATA

18 May 1962

EQUIPMENT	Shovel (Spade)	SURFACE	Turf-Covered Sandy Loam (10' x 50')
Temperature (°F)		Contamination Level	14.6 ±0.7 μc/gm
Air 81	Surface 70-80	Deposition Level	54.9 ±14.6 gm/ft²
Median Time of:		Activity Level	0.80 mc/ft²
Contamination	0649	Dose Rate to Operator	42 mr/hr
Decontamination	1112	Effort	10.50 man-hours/1000 ft²
Time to Decontaminate	126 min	Number of Operators	3

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	25.71	12.18	47.4
10	26.01	13.86	53.3
20	26.66	11.74	44.0
30	28.50	11.15	39.1
40	29.77	9.49	31.9
50	26.94	10.19	37.8
AVERAGE	27.27 ±0.64		42.2 ±3.1

* Values are proportional to the amount of contamination

REMARKS: 1. Ground was fairly moist sandy loam with grass 1-1/2 inches high. No gravel or clay were present.

2. Relative humidity was 80%.

TABLE A-5

TEST-PLOT DECONTAMINATION DATA

16 May 1962

EQUIPMENT Vacuum Cleaner

Temperature (°F)
Air 87 Surface 94
Median Time of:
Contamination 0945
Decontamination 1444
Time to Decontaminate 60 min

SURFACE Turf-Covered Sandy Loam (55' x 10')
Contamination Level 33.2 ±1.1 μc/gm
Deposition Level 47.8 ±1.9 gm/ft²
Activity Level 1.59 mc/ft²
Dose Rate to Operator 75 mr/hr
Effort 1.82 man-hours/1000 ft²
Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	47.28	39.08	82.6
10	45.24	33.98	75.1
20	45.93	36.23	78.9
30	47.37	41.43	87.5
40	49.41	43.92	88.9
50	49.14	40.35	82.1
AVERAGE	47.40 ±0.68		82.5 ±2.1

* Values are proportional to the amount of contamination

REMARKS: 1. The vacuum-cleaner receptacle read 150 mr/hr at 1 foot.

2. Relative humidity was 49%.

TABLE A-6

TEST-PLOT DECONTAMINATION DATA

3 May 1962

EQUIPMENT Lawn Mower (Standard) SURFACE Grass (20' x 100')

Temperature (°F)

Air 76 Surface 80

Median Time of:

Contamination 1442

Decontamination 1517

Time to Decontaminate 15 min

Contamination Level 20.5 ±1.1 μc/gm

Deposition Level 58.1 ±16.1 gm/ft²

Activity Level 1.19 mc/ft²

Dose Rate to Operator 65 mr/hr

Effort 0.13 man-hours/1000 ft²

Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	47.89	50.52	105.5
10	46.01	47.38	103.0
20	47.04	46.95	99.8
30	45.57	46.49	102.0
40	48.54	48.55	100.0
50	48.53	48.64	100.2
60	51.39	51.13	99.5
70	68.04	68.48	100.6
80	51.45	52.97	103.0
90	50.99	51.03	100.1
95	53.57	47.94	89.5
AVERAGE	50.82 ±1.88		103.2 ±1.2

* Values are proportional to the amount of contamination

REMARKS: 1. The grass was 4 inches high.

2. The mower was set at 1.5 inches; 8.5 pounds of grass were removed.

TABLE A-7a

TEST-PLOT DECONTAMINATION DATA

9 May 1962

EQUIPMENT Lawnmower (Toro)

Temperature (°F)
Air 50 Surface 49
Median Time of:
Contamination 1416
Decontamination 1516
Time to Decontaminate 43 min

SURFACE Grass (20' x 100')
First Cutting
Contamination Level 14.1 ±0.7 μc/gm
Deposition Level 70.2 ±2.3 gm/ft²
Activity Level 0.99 mc/ft²
Dose Rate to Operator 60 mr/hr
Effort 0.36 man-hours/1000 ft²
Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	46.10	43.27	93.9
10	48.04	43.95	91.5
20	47.19	42.83	90.8
30	43.39	41.16	94.9
40	43.55	42.04	96.5
50	45.22	42.71	94.4
60	44.81	43.73	97.6
70	47.60	44.46	93.4
80	47.79	46.06	96.4
90	41.81	40.55	97.0
95	44.40	43.46	97.9
AVERAGE	45.45 ±0.62		94.9 ±0.7

* Values are proportional to the amount of contamination

REMARKS:
1. Grass was 5 inches high; mower was set at 2-inch cutting height.
2. 72 cu ft of grass were removed.
3. Relative humidity was 78%.

TABLE A-7b

TEST PLOT DECONTAMINATION DATA

9 May 1962

EQUIPMENT Lawnmower (Toro)

SURFACE Grass (20' x 100')

Temperature (°F)

Air 49 Surface 49

Median Time of:

Contamination 1416

Decontamination 1617

Time to Decontaminate 33 min

Second Cutting

Contamination Level ______ μc/gm

Deposition Level ______ gm/ft²

Activity Level ______ mc/ft²

Dose Rate to Operator 60 mr/hr

Effort 0.63 man-hours/1000 ft²

Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	46.10	42.39	92.0
10	48.04	42.16	87.8
20	47.19	41.38	87.7
30	43.39	38.45	88.6
40	43.55	39.00	89.6
50	45.22	40.74	90.1
60	44.81	40.52	90.4
70	47.60	42.27	88.8
80	47.79	43.54	91.1
90	41.81	38.91	93.1
95	44.40	41.63	93.8
AVERAGE	45.45 ±0.62		90.3 ±0.6

* Values are proportional to the amount of contamination

REMARKS:
1. The Toro was set at a 1-inch cutting height.
2. 30 cu ft of grass were removed containing a measurable amount of activity (dose rate ≈ 40 mr/hr at 3 feet).
3. Effort and % Activity Remaining based on two decons.
4. Relative humidity was 80%.

TABLE A-8

TEST-PLOT DECONTAMINATION DATA

17 May 1962

EQUIPMENT Corn Broom SURFACE Roof (16' x 60')

Temperature (°F)

Air 85 Surface 95

Median Time of:

Contamination 1433

Decontamination 1703

Time to Decontaminate 20 min

Contamination Level 16 2 μc/gm

Deposition Level ______ gm/ft²

Activity Level ______ mc/ft²

Dose Rate to Operator 70 mr/hr

Effort 1 43 man-hours/1000 ft²

Number of Operators 4

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	64.0	12.29	19.2
2	168.C	11.76	7.0
3	55.0	10.72	19 5
4	57.0	9.67	17.0
5	62.0	10.19	16.4
6	72.0	10 19	14.1
7	59.5	12.81	21.5
8	77.0	13.33	17.3
9	68.0	13.85	20.4
10	57.0	15.42	27.0
11	69.0	13.33	19.3
12	92.0	13.85	15.0
AVERAGE	75.0 ±31.1		17.8 ±4.8

* Values are proportional to the amount of contamination

REMARKS: 1. About $\frac{1}{4}$ to $\frac{1}{3}$ of the simulant was blown off by 8-10 mph wind. Some of the sand was blown under the shingles.

2. Measurements 1 through 6 taken 4 ft from roof ridge at 5 ft intervals; 7 through 12 taken 4 ft from eave at 5 ft intervals.

3. Relative humidity was 54%.

TABLE A-9a

TEST-PLOT DECONTAMINATION DATA

4 May 1962

EQUIPMENT Street Broom

SURFACE Roof on building 516 (16' x 120')

Temperature (°F)

Air 77 Surface 76

Median Time of:

Contamination 1125

Decontamination 1206

Time to Decontaminate 29 min

Contamination Level 17.8 μc/gm

Deposition Level 46.1 gm/ft²

Activity Level 1.00 mc/ft²

Dose Rate to Operator 42 mr/hr

Effort 0.65 man-hours/1000 ft²

Number of Operators 2-3

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	80.5	10.2	12.7
2	28.5	7.5	26.3
3	33.5	8.6	25.7
4	23.0	8.0	34.8
5	30.0	9.0	30.0
6	34.0	9.0	26.5
7	42.5	12.3	28.9
8	26.5	8.7	32.8
9	30.0	9.3	31.0
10	46.5	10.0	21.5
11	45.5	8.4	18.5

* Values are proportional to the amount of contamination

REMARKS:
1. Readings were made at 5 ft intervals along a line 4 feet from ridge.
2. Approximately 0.5 inch of rain fell after decon measurements but some sand still remained between the shingles.
3. Averages included in Table A-9b

TABLE A-9b

TEST-PLOT DECONTAMINATION DATA

4 May 1962

EQUIPMENT	Street Broom	SURFACE	Roof of Building 516 (16' x 120')
Temperature (°F)			
Air 77	Surface 76	Contamination Level	μc/gm
Median Time of:		Deposition Level	gm/ft²
Contamination	1125	Activity Level	mc/ft²
Decontamination	1206	Dose Rate to Operator	mr/hr
Time to Decontaminate	29 min	Effort	man-hours/1000 ft²

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	52.5	13.2	25.1
2	28.5	9.6	33.7
3	33.0	8.7	26.4
4	26.5	11.1	41.9
5	30.5	12.5	41.0
6	30.5	12.3	40.3
7	26.0	10.8	41.5
8	25.0	10.7	42.8
9	30.0	10 2	34.0
10	37.5	12.2	32.5
11	35.5	10.7	30.1
12	35.5	9.6	27.0
AVERAGE	35.3 ±12.4		30.7 ±7.7

* Values are proportional to the amount of contamination

REMARKS:

1. Readings were made at 5 ft intervals along a line 4 feet from eave.
2. Averages include values from Table A-9a.

TABLE A-10

TEST-PLOT DECONTAMINATION DATA

17 May 1962

EQUIPMENT Vacuum Cleaner
SURFACE Roof (16' x 60')

Temperature (°F)
Air 85 Surface 95
Median Time of:
Contamination 1428
Decontamination 1706
Time to Decontaminate 105 min

Contamination Level 16.2 μc/gm
Deposition Level ____ gm/ft²
Activity Level ____ mc/ft²
Dose Rate to Operator 65 mr/hr
Effort 1.88 man-hours/1000 ft²
Number of Operators 1

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	98.0	1.05	1.1
2	55.0	1.36	2.5
3	73.0	1.46	2.0
4	63.0	1.46	2.3
5	56.0	1.57	2.8
6	50.0	1.88	3.8
7	53.0	2.72	5.1
8	56.5	2.51	4.4
9	57.0	1.99	3.5
10	51.0	2.20	4.3
AVERAGE	61.3 ±14.5		3.2 ±0.4

* Values are proportional to the amount of contamination

REMARKS:
1. The activity level (mc/ft²) was not obtained because of a 10-12 mph wind blew about ⅓ of the simulant off the roof by the time the decon operation had started.
2. Measurements 1 through 5 taken 4 ft from roof ridge at 5 ft intervals; 6 through 10 taken 4 ft from roof eave at 5 ft intervals.
3. Relative humidity was 51%.

TABLE A-11

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Water Hose (8 psig) SURFACE Roof (15' x 20')

Temperature (°F)

Air 56 Surface 54

Median Time of:

Contamination 1655

Decontamination 1715

Time to Decontaminate 12 min

Contamination Level 17.1 ±0.8 μc/gm

Deposition Level 38.6 ±3.2 gm/ft²

Activity Level 0.66 mc/ft²

Dose Rate to Operator 35 mr/hr

Effort 0.67 man-hours/1000 ft²

Number of Operators 1

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	53.0	3.4	6.4
2	52.5	6.6	12.6
3	47.5	7.3	15.4
4	62.5	9.1	14.6
5	57.5	8.0	13.9
6	58.0	5.8	10.0
7	49.0	5.2	10.6
8	59.0	8.0	13.5
9	58.0	10.6	18.3
10	60.0	6.9	11.5
11	59.0	5.7	9.7
12	65.5	4.9	7.5
AVERAGE	56.8 ±5.3		12.0 ±3.4

* Values are proportional to the amount of contamination

REMARKS:
1. Twenty-eight gallons of water were used on the roof (0.093 gal/ft²).
2. Roof area was subdivided into twelve 5 ft squares. Measurements were taken in center of squares; numbers 1 through 4 along roof ridge, numbers 5 through 8 along central portion, numbers 9 through 12 along roof eave.
3. Relative humidity was 82%.

TABLE A-12a

TEST-PLOT DECONTAMINATION DATA

4 May 1962

EQUIPMENT Water Hose (35 psig) SURFACE Roof of Building 517 (ridge) (16' x 120')

Temperature (°F)
Air 81 Surface 80
Median Time of:
Contamination 1429
Decontamination 1505
Time to Decontaminate 26 min

Contamination Level 16.8 μc/gm
Deposition Level 45.4 gm/ft²
Activity Level 0.76 mc/ft²
Dose Rate to Operator 23 mr/hr
Effort 0.23 man-hours/1000 ft²
Number of Operators 1

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	40.0	3.0	7.5
2	39.5	4.3	10.9
3	36.0	6.8	18.9
4	36.5	3.3	9.0
5	39.0	3.4	8.7
6	33.5	6.3	18.8
7	36.5	3.8	10.4
8	32.5	3.7	11.4
9	34.0	5.0	14.7
10	36.5	4.7	12.9
11	35.5	4.5	12.7
12	31.5	4.6	14.6

* Values are proportional to the amount of contamination

REMARKS: 1. 131 gallons water were used over the entire roof (0.068 gal/ft²).
2. Averages included in Table A-12b.

TABLE A-12b

TEST-PLOT DECONTAMINATION DATA

4 May 1962

EQUIPMENT Water Hose (35 psig) SURFACE Roof of Building 517 (eaves) (16' x 120')

Temperature (°F)

Air 81 Surface 80

Median Time of:

Contamination 1428

Decontamination 1506

Time to Decontaminate 26 min

Contamination Level ________ μc/gm

Deposition Level ________ gm/ft²

Activity Level ________ mc/ft²

Dose Rate to Operator ________ mr/hr

Effort ________ man-hours/1000 ft²

Measurement number	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
1	66.5	7.3	11.0
2	40.5	6.5	16.0
3	42.5	9.3	21.9
4	41.0	7.5	18.3
5	34.0	8.2	24.1
6	36.0	9.6	26.7
7	40.5	8.1	20.0
8	43.0	7.9	18.4
9	39.5	10.5	26.6
10	39.5	9.5	24.0
11	33.5	7.6	22.7
12	42.0	8.2	19.5
AVERAGE	38.7 ±6.8		16.7 ±5.8

* Values are proportional to the amount of contamination

REMARKS: 1. Averages include values from Table A-12a.

TABLE A-13

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Corn Broom

Temperature (°F)

Air 56 Surface 54

Median Time of:

Contamination 1810

Decontamination 1953

Time to Decontaminate 27 min

SURFACE Macadam (20' x 55')

Contamination Level 14.0 ±0.7 μc/gm

Deposition Level 46.0 ±12.1 gm/ft²

Activity Level 0.64 mc/ft²

Dose Rate to Operator 70-230 mr/hr

Effort 1.24 man-hours/1000 ft²

Number of Operators 3

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	64.48	14.21	22.0
10	68.66	18.16	26.4
20	64.70	16.63	25.7
30	64.47	12.07	18.7
40	62.70	8.65	13.8
AVERAGE	65.00 ±0.98		21.3 ±2.3

* Values are proportional to the amount of contamination

REMARKS: 1. The amount of sand and dirt removed was 165 pounds.

2. Relative humidity was 84%; wind velocity was 3-5 mph.

TABLE A-14

TEST PLOT DECONTAMINATION DATA

2 May 1962

EQUIPMENT Street Broom
Temperature (°F)
Air 67 Surface 72
Median Time of:
Contamination 1249
Decontamination 1355
Time to Decontaminate 31 min

SURFACE Macadam (20' x 100')
Contamination Level 25.9 ±0.9 μc/gm
Deposition Level 35.4 ±11.9 gm/ft²
Activity Level 0.92 mc/ft²
Dose Rate to Operator 100 mr/hr
Effort 1.03 man-hours/1000 ft²
Number of Operators 4

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	63.91	45.40	71.0
10	61.46	50.90	82.8
20	61.87	41.25	66.7
30	63.26	42.65	67.4
40	65.66	49.03	74.7
50	64.07	46.19	72.1
60	66.50	49.48	74.4
70	65.16	38.24	58.7
80	61.54	48.56	78.9
90	63.69	60.43	94.9
95	67.06	59.23	88.3
AVERAGE	64.02 ±0.50		75.4 ±3.1

* Values are proportional to the amount of contamination

REMARKS: 1. To decontaminate, three men used brooms and one a shovel.

2. 517 pounds of gravel were removed from the plot by decontamination.

TABLE A-15

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Vacuum Cleaner

SURFACE Macadam (20' x 45')

Temperature (°F)

Air 56 Surface 54

Median Time of:

Contamination 1813

Decontamination 1950

Time to Decontaminate 85 min

Contamination Level 14.0 ±0.7 μc/gm

Deposition Level 46.0 ±12.1 gm/ft²

Activity Level 0.64 mc/ft²

Dose Rate to Operator 68 mr/hr

Effort 1.57 man-hours/1000 ft²

Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	59.39	0.48	0.8
10	58.54	0.17	0.3
20	50.46	0.67	1.3
30	60.46	0.51	0.8
AVERAGE	57.21 ±2.28		0.8 ±0.2

* Values are proportional to the amount of contamination

REMARKS: 1. 150 pounds of sand and dirt were removed.

2. The vacuum cleaner receptacle was reading 400 mr/hr at 3 feet.

3. Relative humidity was 82%.

TABLE A-16

TEST-PLOT DECONTAMINATION DATA

17 May 1962

EQUIPMENT Water Hose (35 psig) SURFACE Macadam (20' x 45')

Temperature (°F)

Air 82 Surface 90

Median Time of:

Contamination 0959

Decontamination 1609

Time to Decontaminate 66 min

Contamination Level 17.9 ±1.1 μc/gm

Deposition Level 44.3 ±2.7 gm/ft²

Activity Level 0.79 mc/ft²

Dose Rate to Operator 30-210 mr/hr

Effort 1.22 man-hours/1000 ft²

Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	61.38	0.89	1.4
10	61.07	0.89	1.4
20	63.66	0.88	1.4
30	64.17	1.21	1.9
40	61.02	2.36	3.9
AVERAGE	62.26 ±0.68		2.0 ±0.5

* Values are proportional to the amount of contamination

REMARKS: 1. 357 gallons of water were used in the decontamination (0.397 gal/ft²).

2. Wet sand and dirt were removed at 10-ft intervals by shovel.

3. Relative humidity was 52%.

TABLE A-17

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Corn Broom — SURFACE Concrete (20' x 60')

Temperature (°F)
Air 60 Surface 59
Median Time of:
Contamination 1324
Decontamination 1355
Time to Decontaminate 18 min

Contamination Level 15.7 ±0.7 μc/gm
Deposition Level 47.8 ±4.1 gm/ft²
Activity Level 0.75 mc/ft²
Dose Rate to Operator 50-160 mr/hr
Effort 0.50 man-hours/1000 ft²
Number of Operators 2

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	46.56	1.13	2.4
12	46.00	2.04	4.4
19	48.49	1.91	3.9
26	44.03	2.41	5.5
33	48.89	1.25	2.6
40	48.86	2.61	5.3
47	41.19	1.30	3.2
54	49.83	2.00	4.0
AVERAGE	46.71 ±1.03		3.9 ±0.4

* Values are proportional to the amount of contamination

REMARKS: 1. Eighty-eight pounds of sand and dirt were removed from the plot.

2. Pickup of sand was required at intervals of 30 feet.

3. Relative humidity was 81%.

TABLE A-18

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Street Broom SURFACE Concrete (20' x 60')

Temperature (°F)

Air 55 Surface 58

Median Time of:

Contamination 1103

Decontamination 1134

Time to Decontaminate 20 min

Contamination Level 16.0 ±0.7 μc/gm

Deposition Level 48.7 ±3.9 gm/ft²

Activity Level 0.78 mc/ft²

Dose Rate to Operator 50 mr/hr

Effort 0.56 man-hours/1000 ft²

Number of Operators 2

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	46.39	1.88	4.0
12	45.81	2.85	6.2
19	43.93	2.76	6.3
26	44.64	1.71	3.8
33	45.27	2.89	6.4
40	44.84	2.02	4.5
47	45.39	1.88	4.1
54	49.56	2.23	4.5
AVERAGE	45.73 ±0.61		5.0 ±1.1

* Values are proportional to the amount of contamination

REMARKS: 1. 82 pounds of sweepings were removed from plot area.

2. Relative humidity was 75%.

TABLE A-19

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Vacuum Cleaner SURFACE Concrete (20' x 60')

Temperature (°F)
Air 53 Surface 54
Median Time of:
Contamination 0928
Decontamination 1034
Time to Decontaminate 50 min

Contamination Level 17.7 ±1.1 μc/gm
Deposition Level 47.7 ±6.9 gm/ft²
Activity Level 0.84 mc/ft²
Dose Rate to Operator 48 mr/hr
Effort 0.69 man-hours/1000 ft²
Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	51.02	0.67	1.3
12	49.39	0.60	1.2
19	49.40	0.90	1.8
26	49.13	0.68	1.4
33	51.07	0.93	1.8
40	50.99	1.03	2.0
47	50.01	0.61	1.2
54	51.25	0.53	1.0
AVERAGE	50.28 ±0.32		1.5 ±0.1

* Values are proporti[illegible]al to the amount of contamination

REMARKS: 1. The nozzle of the vacuum cleaner had a rubber pad fitted to make close contact with the surface and thus provide maximum suction.
2. The vacuum cleaner receptacle was reading 2.5 r/hr at 6 inches after one-half of plot was decontaminated.
3. Relative humidity was 85%.

TABLE A-20

TEST-PLOT DECONTAMINATION DATA

11 May 1962

EQUIPMENT Water Hose (35 psig) SURFACE Concrete (20' x 60')

Temperature (°F)

Air 58 Surface 57

Median Time of:

Contamination 1418

Decontamination 1514

Time to Decontaminate 40 min

Contamination Level 16.0 ±0.7 μc/gm

Deposition Level 46.1 ±3.5 gm/ft²

Activity Level 0.73 mc/ft²

Dose Rate to Operator 60 mr/hr

Effort 0.56 man-hours/1000 ft²

Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	62.76	0.48	0.8
12	54.86	0.56	1.0
19	51.78	0.55	1.1
26	50.41	1.36	2.7
33	49.73	0.92	1.8
40	52.90	1.41	2.7
47	51.57	0.91	1.8
54	53.55	0.80	1.5
AVERAGE	53.45 ±1.45		1.7 ±0.3

* Values are proportional to the amount of contamination

REMARKS:
1. A 100-ft garden hose with a 5/8-inch bore and 3/4-inch nozzle was used.
2. 239 gallons of water were used (0.199 gal/ft²).
3. 103 pounds of wet sand were removed from the plot.
4. Relative humidity was 73%.

TABLE A-21

TEST-PLOT DECONTAMINATION DATA

18 May 1962

EQUIPMENT Corn Broom

SURFACE Asphalt (20' x 100')

Temperature (°F)

Air 87 Surface 86

Contamination Level 11.9 ±0.7 μc/gm

Median Time of:

Deposition Level 49.4 ±5.6 gm/ft^2

Contamination 1724

Activity Level 0.59 mc/ft^2

Decontamination 1808

Dose Rate to Operator 60-250 mr/hr

Time to Decontaminate 24 min

Effort 0.60 man-hours/1000 ft^2

Number of Operators 3

Distance from end (ft).	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	35.69	1.12	3.1
10	34.88	1.49	4.3
20	34.88	1.96	5.6
30	33.07	3.03	9.2
40	31.76	3.44	10.8
50	33.61	3.27	9.7
60	37.50	3.72	9.9
70	36.25	3.13	8.6
80	37.01	3.82	10.3
90	33.71	4.65	13.8
95	32.67	5.32	16.3
AVERAGE	34.64 ±0.56		9.2 ±1.2

* Values are proportional to the amount of contamination

REMARKS: 1. Pickup of sand was required at intervals of 50 feet.

2. Relative humidity was 63%.

TABLE A-22

TEST-PLOT DECONTAMINATION DATA

8 May 1962

EQUIPMENT Street Broom SURFACE Asphalt (20' x 100')

Temperature (°F)

Air 52 Surface 58

Median Time of:

Contamination 1624

Decontamination 1719

Time to Decontaminate 28 min

Contamination Level 21.3 ±0.8 μc/gm

Deposition Level 46.9 ±2.2 gm/ft^2

Activity Level 1.00 mc/ft^2

Dose Rate to Operator 70-440 mr/hr

Effort 0.47 man-hours/1000 ft^2

Number of Operators 2

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	86	10.3	12.0
10	87	10.5	12.1
20	90	12.3	13.7
30	91	14.1	15.5
40	85	14.6	17.2
50	85	11.6	13.6
60	84	16.5	19.6
70	87	17.8	20.4
80	99	15.4	15.5
90	84	14.9	17.7
95	82	13.7	16.7
AVERAGE	80 ±1		15.8 ±0.8

* Values are proportional to the amount of contamination

REMARKS: 1. Sweepings were removed from plot area at intervals of 50 feet.

TABLE A-23

TEST-PLOT DECONTAMINATION DATA

2 May 1962

EQUIPMENT Vacuum Cleaner
Temperature (°F)
Air 71 Surface 75
Median Time of:
Contamination 1500
Decontamination 1751
Time to Decontaminate 114 min

SURFACE Asphalt (20' x 100')
Contamination Level 23.4 ±1.1 μc/gm
Deposition Level 27.5 ±0.7 gm/ft²
Activity Level 0.64 mc/ft²
Dose Rate to Operator 95 mr/hr
Effort 0.95 man-hours/1000 ft²
Number of Operators 1

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	50.29	0.03	0.0
10	56.31	0.03	0.0
20	46.85	0.07	0.1
30	55.34	0.15	0.3
40	61.54	0.29	0.5
50	44.17	0.29	0.7
60	39.67	0.31	0.8
70	53.31	0.48	0.9
80	54.01	0.63	1.1
90	49.51	0.86	1.7
95	51.48	0.94	1.8
AVERAGE	51.13 ±1.83		0.7 ±0.2

* Values are proportional to the amount of contamination

REMARKS: 1. The asphalt surface was smooth and free from sand and rocks.

2. Wind velocity was 7-12 mph.

TABLE A-24

TEST-PLOT DECONTAMINATION DATA

3 May 1962

EQUIPMENT Water Hose	SURFACE Asphalt (20' x 100')
Temperature (°F)	
Air 76 Surface 70	Contamination Level 24.9 ±1.4 μc/gm
Median Time of:	Deposition Level 47.7 ±1.3 gm/ft²
Contamination 1025	Activity Level 1.19 mc/ft²
Decontamination 1553	Dose Rate to Operators 70-100 mr/hr
Time to Decontaminate SEE REMARK ONE BELOW	Effort 4.44 (8 psi) man-hours/1000 ft²
Number of Operators 1	Effort 1.25(35 psi) man-hours/1000 ft²

Distance from end (ft)	Contamination radiation level*	Decontamination radiation level*	Activity remaining (%)
5	78.35	2.43	3.1
10	79.68	4.06	5.1
20	79.47	2.58	3.2
30	80.43	1.84	2.3
40	78.33	1.80	2.3
50	115.47	3.66	3.2
60	79.60	3.13	3.9
70	80.12	1.56	1.9
80	77.71	1.26	1.6
90	75.62	1.44	1.9
95	75.50	1.44	1.9
AVERAGE	81.84 ±3.40		2.8 ±0.3

* Values are proportional to the amount of contamination

REMARKS: 1. The first 15 ft was conducted at 8 psi, requiring 80 min and 108 gal of water (0.36 gal/ft²). Remainder of plot was conducted at 35 psi. For a 400 ft² area, 30 min and 93 gal of water (0.23 gal/ft²) was required.

2. Pickup of sand was required at intervals of 15 ft.

APPENDIX B

METHODS OF ANALYSIS

I. PERCENTAGE OF ACTIVITY REMAINING.

Percentage of activity remaining is calculated from each measurement point or scan, with the radiation intensity measured over the contaminated area, R_c, and the intensity measured after decontamination, R_d, corrected for decay to the time of the contaminated plot measurement. As the magnitude of current emitted from the detecting element is directly proportional to the radiation intensity, the current measurements were used to calculate the percentages. Figure B is a typical set of X-Y curves recorded in the field. The area generated under the current-versus-distance graph when the test plot was scanned is directly proportional to the average radiation intensity across the test plot. Percentage of activity remaining was calculated in both cases by

$$\% \text{ activity remaining} = A = \frac{R_d}{R_c}(100) \qquad (1)$$

II. AVERAGE PERCENTAGE OF ACTIVITY REMAINING.

The average percentage of activity remaining over a test plot was calculated as an arithmetic mean of the individual measurement points or scans.

$$\bar{A} = \frac{\Sigma A}{N} \qquad (2)$$

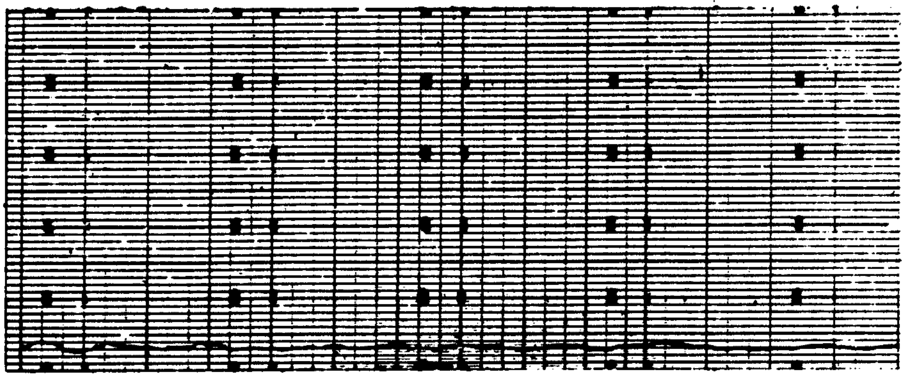
Where: N = number of points or scans.

III. STANDARD DEVIATION OF ACTIVITY REMAINING.

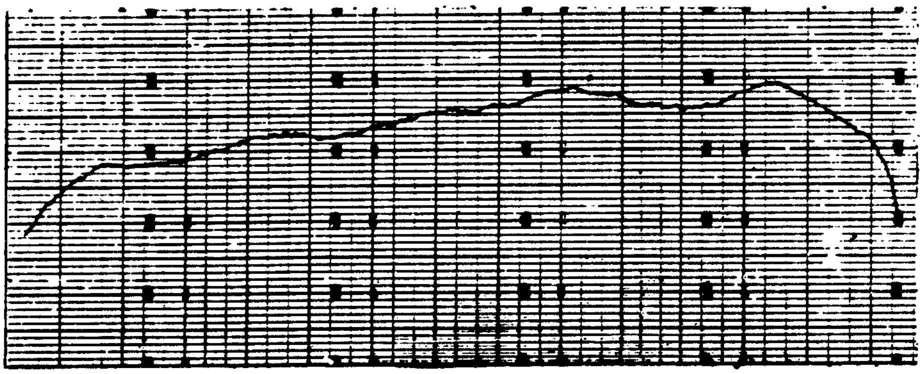
The standard deviation about the calculated average percentage of activity remaining was calculated from the equation

$$s = \sqrt{\frac{N \Sigma A^2 - (\Sigma A)^2}{N(N-1)}} \qquad (3)$$

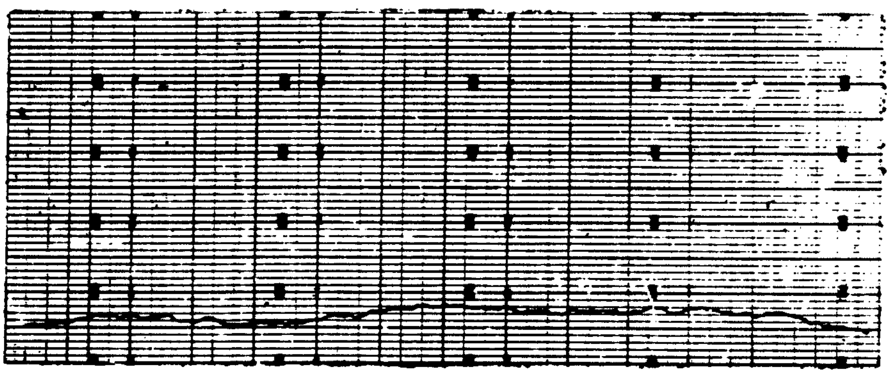
However, when using data obtained from scans, the standard deviation was calculated by dividing the above equation by $\sqrt{N}$. This is permissable as the radiation equivalent data from scans are average values.



Background Scan (3×10^{-9})



Scan of Contaminated Plot (10×10^{-9})



Scan of Decontaminated Plot (3×10^{-9})

Figure B - Typical X-Y Recordings of Scan Information

IV. CONFIDENCE INTERVALS.

All confidence intervals presented in this report are at a 90% confidence level. For point measurement data, the confidence interval is 1.645 times the standard deviation. The confidence interval for averages of scanned data was calculated by multiplying the modified standard deviation by the suitable value taken from a table of student's t distribution. Following are the t values for 90% confidence level used for the various numbers of scans encountered in this series:

Number of Scans	Percentiles of t
4	2.35
5	2.13
6	2.02
7	1.94
8	1.90
9	1.86
10	1.83
11	1.81

V. SAMPLE PAN DATA.

The averages and standard deviations given for the mass level and specific activity of sand were calculated from equations (1), (2), and (3) for point measurements.

VI. MODEL FOR RADIATION FROM ADJACENT AREAS.

The method for estimating the effect of decontamination of an immediately adjacent area was based on radiation intensity ratios expected from various sizes of rectangular areas. These ratios are presented in tabular form in NDL-TR-11. The procedure is to determine from the tables the factor of radiation expected from a certain size area. From this value, the factor of a subarea that has been decontaminated is subtracted. The result is the expected radiation factor for 100% decontamination of the subarea. Since this was usually not the case, the percentage of activity remaining times the subarea factor must be added back into the resulting factor. Where shielding of earth is applicable, the factor that is added to the result must be further modified.

For example, suppose the radiation intensity reduction is to be determined at the center of one side of a 40-foot square test plot,

of which the one-half next to the observer has a remaining activity of 20% - the resulting factor may be determined as follows:

1. Factor for 40 foot square = 2(3.580) = 7.160

2. Factor for 40- by 20-foot area = 2(3.144) = 6.288

3. Resulting factor from 100% decontamination = 7.160 - 6.288 = 0.872

4. Factor from decontaminated area = (6.288) (0.20) = 1.258

5. Resulting factor = 0.872 + 1.258 = 2.130

6. Percentage radiation remaining = $\frac{2.130}{7.160}$ (100) = 29.7%

To extend the above example to include an 0.7 shielding factor from the decontaminated area, the final solution would be

$$\text{Percentage radiation remaining} = \frac{0.872 + (0.7)(1.258)}{7.160} (100) = 24.5\%$$

VII. INFINITE FIELD CALCULATION.

To determine the effectiveness of the decontamination of a specified area in an infinite fallout field, certain assumptions were made to simplify the calculation. It was assumed that all radiation received at a point was from an area within a 100-foot radius about that point, and that there was no attenuation or scattering by the air. The radiation intensity factor at the center of this area was 22.029. The radiation factor of any decontaminated area may be subtracted from the circle's factor and from the percentage of remaining radiation calculated.

APPENDIX C

BUILDING COMPLEX TEST

I. MEASUREMENT POINTS.

The positions where radiation measurements were taken are given in figures C.1, C.2, and C.3. All measurements were taken with a "cutie-pie" at a height of 3 feet above the ground, roof, or building floor. Tables C.1, C.2, and C.3 give radiation measurements taken at the points illustrated in the correspondingly numbered figures. Table C.4 summarizes decontamination times and dose rates during the complex operation.

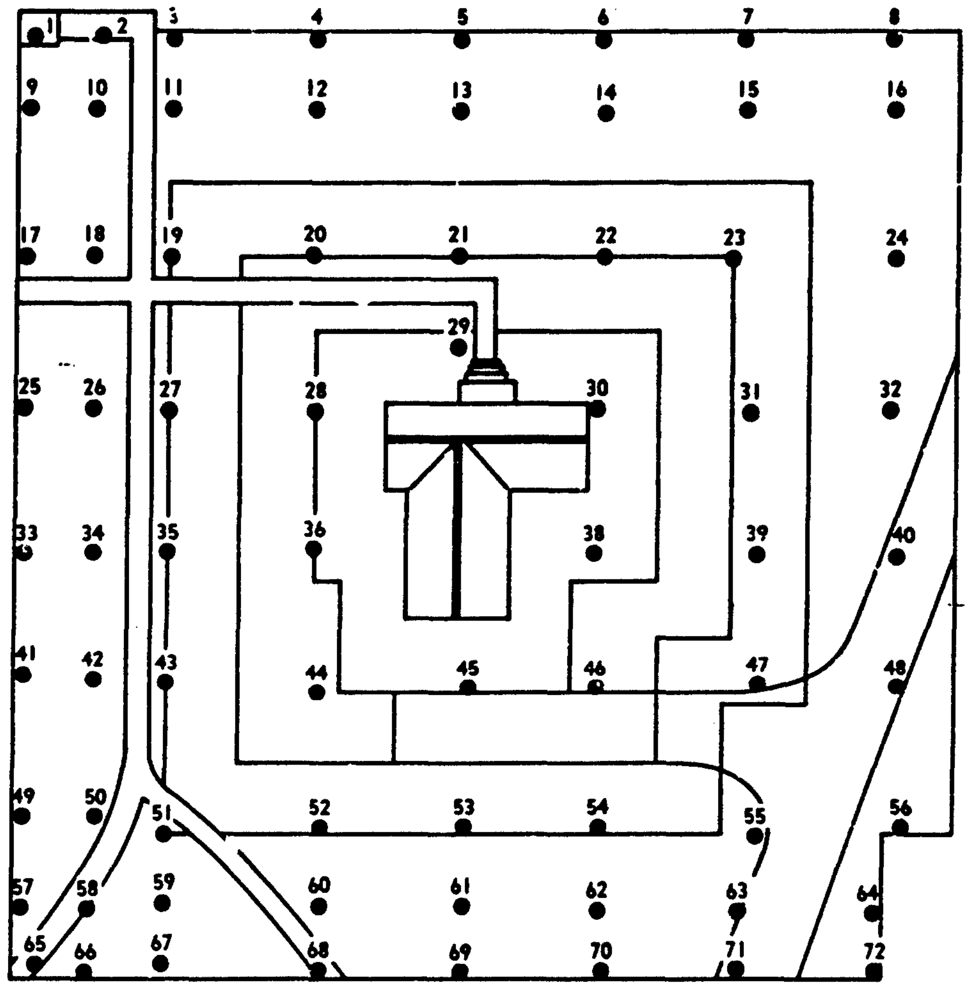


Figure C.1 - Location of Reading Stations on the Complex

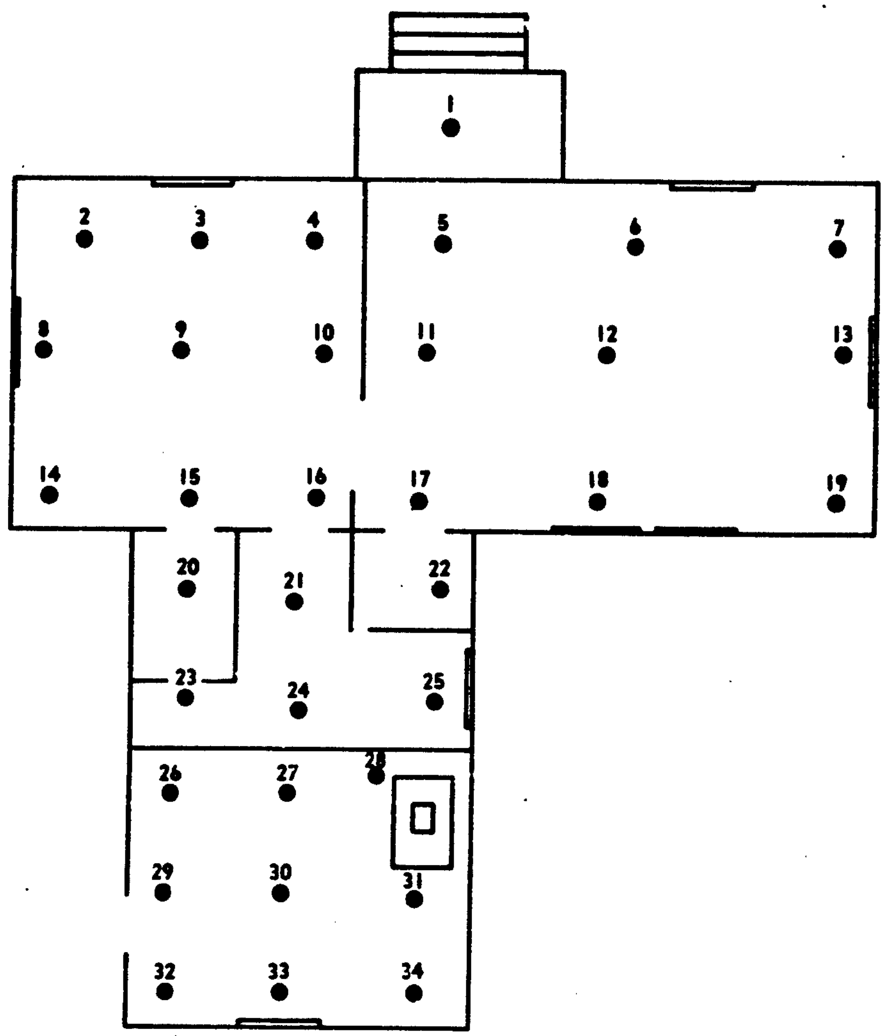


Figure C.2 - Location of Reading Stations Inside Building on the Complex

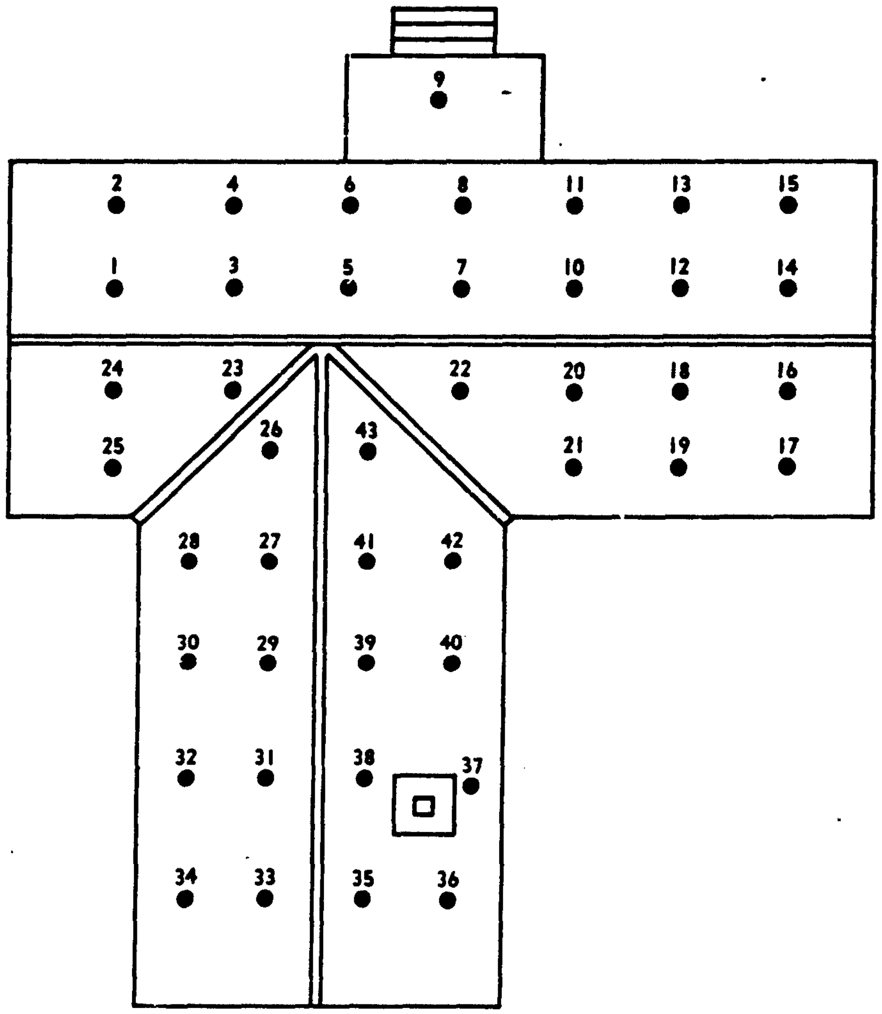


Figure C.3 - Location of Read'ng Stations on Roof of Building on the Complex

TABLE C.1

RADIATION LEVELS ON GROUND OF COMPLEX

Reading Station	After Contamination (mr/hr)	After Decon† (mr/hr)	% Remaining After Decon	% Decrease	Reading Station	After Contamination (mr/hr)	After Decon† (mr/hr)	% Remaining After Decon	% Decrease
1	6.5	0.83	12.8	87.2	37	-	-	-	-
2	9	1.65	18.3	81.7	38*	150	9.08	6.1	93.9
3	10	2.48	24.8	75.2	39*	130	33.83	26.0	74.0
4	13	2.48	19.1	80.9	40	30	9.9	33.0	67.0
5	16	3.30	20.6	79.4	41	13	2.48	19.1	80.9
6	15	2.48	16.5	83.5	42	21	4.95	23.6	76.4
7	13	2.48	19.1	80.9	43*	70	11.47	16.4	83.6
8	9	1.65	18.3	81.7	44*	160	57.75	36.1	63.9
9	8.5	1.65	19.4	80.6	45*	170	23.93	14.1	85.9
10	12	2.48	20.7	79.3	46*	135	52.8	39.1	60.9
11	17	3.30	19.4	80.6	47*	155	49.5	31.9	68.1
12	23	5.78	25.1	74.9	48	75	24.4	35.2	64.8
13	24	4.95	20.6	79.4	49	9	1.65	18.3	81.7
14	24	4.95	20.6	79.4	50	14	3.30	23.6	76.4
15	25	5.78	23.1	76.9	51*	35	6.60	18.9	81.1
16	12	2.48	20.6	79.4	52*	65	21.45	33.0	67.0
17	11	2.48	22.5	77.5	53*	80	26.4	33.0	67.0
18	20	4.95	24.7	75.3	54*	80	23.1	28.9	71.1
19*	95	28.1	29.6	70.4	55	65	22.28	34.3	65.7
20*	125	40.4	32.3	67.7	56	14.5	11.55	79.7	20.3
21*	80	18.2	22.8	77.2	57	7	1.65	23.6	76.4
22*	125	34.7	27.7	72.3	58	10	2.48	24.8	75.2
23*	160	57.75	36.1	63.9	59	13.5	3.30	24.4	75.6
24	23	6.6	28.7	71.3	60	20	5.78	28.9	71.1
25	13.5	2.48	18.4	81.6	61	21	5.78	27.5	72.5
26	23	5.78	25.1	74.9	62	21	6.60	31.4	68.6
27*	80	25.58	32.0	68.0	63	17	6.60	38.8	61.2
28*	135	33.83	25.1	74.9	64	10	4.13	41.3	58.7
29*	220	49.5	22.5	77.5	65	5	1.65	33.0	67.0
30*	135	7.43	5.5	94.5	66	7	1.65	23.6	76.4
31*	135	32.18	23.8	76.2	67	10	2.48	24.8	75.2
32	30	9.08	30.3	69.7	68	12.5	3.30	26.4	73.6
33	14	2.48	17.7	82.3	69	13	3.30	25.4	74.6
34	22	5.78	26.3	73.7	70	12	3.30	27.5	72.5
35*	65	19.8	30.5	69.5	71	10.5	4.13	39.3	60.7
36*	145	33.0	22.8	77.2	72	6.5	2.48	38.2	61.8
							Average	25.8	74.2±1.9

† Corrected for decay
*These stations located in area where contaminant had been spread.

TABLE C.2

RADIATION LEVELS INSIDE BUILDING ON THE COMPLEX

Reading Station	After* Roof Contamination (mr/hr)	After Roof & Ground Contamination (mr/hr)	Roof Decontaminated Ground Contaminated			Roof Decontaminated Ground Decontaminated 10 ft Out From Bldg			Roof Decontaminated Ground Decontaminated 30 ft Out From Bldg		
			Reading (mr/hr)	% Remaining	% Decrease	Reading (mr/hr)	% Remaining	% Decrease	Reading (mr/hr)	% Remaining	% Decrease
1	25	95	93.2	98.1	1.9	46.2	48.6	51.4	20.5	21.1	78.9
2	30	81	83.9	103.6	- 3.6	35.4	43.7	56.3	13.9	17.2	82.8
3	30	80	56.9	71.1	28.9	31.6	39.5	60.5	13.1	16.3	83.7
4	37	80	64.2	80.3	19.7	29.3	36.6	63.4	12.3	15.4	84.6
5	35	80	51.8	64.8	35.2	32.3	40.4	59.6	14.7	18.3	81.7
6	30	70	51.8	74.5	25.5	29.3	41.9	58.1	10.6	15.1	84.9
7	25	85	74.5	87.8	12.2	33.1	39.0	61.0	10.6	12.4	87.6
8	25	80	67.2	84.0	16.0	31.6	39.5	60.5	13.1	16.4	83.6
9	33	75	48.6	65.0	35.0	27.0	36.0	64.0	10.6	14.1	85.9
10	35	70	42.4	60.6	39.4	25.4	36.3	63.7	11.5	16.4	83.6
11	40	65	44.5	68.5	31.5	-	-	-	10.6	16.3	83.7
12	35	70	51.8	74.0	26.0	24.6	35.2	64.8	9.8	14.0	86.0
13	25	70	51.8	74.0	26.0	23.1	33.0	67.0	8.2	11.7	88.3
14	25	80	91.4	114	-14	30.8	38.5	51.5	13.1	16.4	83.6
15	33	70	55.9	80.0	20.0	23.9	34.2	65.8	10.6	15.1	84.9
16	35	60	37.3	62.2	37.8	20.0	33.3	66.7	8.2	13.7	86.3
17	50	65	46.6	71.8	28.2	20.8	32.0	68.0	9.0	13.8	86.2
18	35	70	55.9	79.8	20.2	22.3	31.9	68.1	9.0	12.9	87.1
19	28	80	77.6	97.1	2.9	24.6	30.8	69.2	9.0	11.3	88.7
20	30	75	69.3	92.4	7.6	24.6	32.8	67.2	10.6	14.1	85.9
21	35	60	41.4	69.0	31.0	19.3	32.2	67.8	8.2	13.7	86.3
22	35	65	56.9	87.5	12.5	19.3	29.7	70.3	8.2	12.6	87.4
23	30	80	67.3	84.2	15.8	27.0	33.8	66.2	12.3	15.4	84.6
24	30	55	37.3	67.8	32.2	17.7	32.2	67.8	7.4	13.5	86.5
25	25	60	53.8	89.7	10.3	17.7	29.5	70.5	7.4	12.3	87.7
26	22	80	91.1	114	-14	26.2	32.8	67.2	12.3	15.4	84.6
27	21	40	29.0	72.5	27.5	13.1	32.8	67.2	5.7	14.3	85.7
28	19	35	16.6	47.4	52.6	8.5	24.3	75.7	4.9	14.0	86.0
29	23	95	103.5	109	- 9	29.3	30.9	69.1	14.7	15.5	84.5
30	27	55	41.4	75.3	24.7	16.9	30.8	69.2	7.4	13.5	86.5
31	13	65	80.7	124.3	-23.4	16.9	26.0	74.0	6.5	10.0	90.0
32	18	90	103.5	115	-15	31.6	35.2	64.8	12.3	12.3	87.7
33	18	70	60.0	85.8	14.2	18.5	26.4	73.6	7.4	10.6	89.4
34	14	90	99.4	110	-10	20.0	22.2	77.8	8.2	9.1	90.9
			Averages	84.0	16 ± 3.2		34.0	66.0±1.0		14.3	85.7 ± .5

*Readings taken approx. one hour previous to remaining data on page. Same time as readings in Table VII.

TABLE C.3

RADIATION LEVELS ON ROOF OF BUILDING ON COMPLEX
(mr/hr)

Reading Station	Roof Contaminated	Roof Decon; Ground Contam. 30 ft Out From Bldg	Roof Decon; Ground Decon 10 ft Out From Bldg	Roof Decon; Ground Decon 30 ft Out From Bldg
1	95	47.3	33.2	19.9
2	65	63.0	36.2	21.6
3	100	47.3	31.7	20.8
4	75	63.0	36.2	22.4
5	110	47.3	31.0	23.2
6	85	63.0	36.2	24.1
7	105	46.2	31.7	22.4
8	95	63.0	36.2	24.9
9	60	68.3	42.3	24.1
10	100	49.4	31.7	21.6
11	80	60.9	36.2	23.2
12	95	47.3	32.5	20.8
13	70	60.9	35.5	22.4
14	90	47.3	32.5	20.8
15	65	62.0	36.2	21.6
16	95	49.4	29.4	17.4
17	80	68.3	31.7	19.1
18	110	49.4	27.9	17.4
19	100	68.3	30.2	19.1
20	115	50.4	27.2	18.3
21	125	68.3	35.5	23.2
22	145	52.5	31.7	22.4
23	135	47.3	30.2	19.1
24	90	47.3	29.4	17.4
25	110	57.8	32.5	19.9
26	135	45.2	29.7	19.1
27	120	47.3	31.0	19.1
28	105	59.9	32.5	19.9
29	110	48.3	31.0	19.1
30	90	59.9	21.0	19.1
31	115	48.3	31.7	19.1
32	95	63.0	31.7	19.1
33	115	52.5	34.0	20 8
34	80	60.9	34.0	19.9
35	105	52.5	31.0	19.1
36	75	63.0	31.7	18.3
37	55	52.5	25.7	14.9
38	100	31.5	18.9	12.5
39	120	57.8	27.9	16.6
40	85	48.3	26.4	17.4
41	135	68.3	34.7	22.4
42	135	52.5	31.0	20.8
43	155	52.5	31.7	22.4

TABLE C.4

SUMMARY OF DECONTAMINATION TIMES AND DOSE RATES TO OPERATOR (COMPLEX)

Surface	Method	Elapsed Time (min)	Number of Personnel	Man-Hours	Dose Rate to Operator (mr/hr)
Roof	Waterhosing (35 psig)	14	1	0.23	45 to 85
Porch, Floor, & Steps	Sweeping with Corn Broom	0.5	1	0.008	100 to 110
Ground 0-10 ft from Bldg* (1st day)	Removing Turf	57	4 Shovelers 2 Wheel-barrowers	5.7	80 to 100 17
Ground 0-10 ft from Bldg (2nd day)	with Shovel	85	5 Shovelers 2 Wheel-barrowers	9.9	50 to 75 15
Coal Pad (9' x 13')	Sweeping with Corn Broom	6	1	0.1	60 to 90
Asphalt Drive-way**	Sweeping with Corn Broom	13	1	0.22	70 to 110
Ground 10-30 ft from Bldg	Turning earth with Garden Plow	176	1	2.9	45 to 55
Macadam Sidewalk (3' x 45')	Sweeping with Corn Broom	6	1	0.1	60 to 150

*Decontamination operations stopped because of rain after completing approximately one-third of the strip. Decontamination completed next day.

**Crosswind blowing sand into the turf; only swept one-half of the driveway.

APPENDIX D

HEALTH PHYSICS PROGRAM

Health physics activities during the spring series of decontamination tests were essentially a continuation of the previously reported activities in connection with the cold-weather decontamination tests. Differences were encountered, however, in that the manual character of the decontamination techniques and the somewhat higher concentration of fallout simulant used led to higher personnel exposures and more stringent health physics control.

I. PRE-TEST SURVEY.

Upon arrival at Camp McCoy one of the first tasks accomplished was the counting of samples taken from some of the areas that were highly contaminated during the winter tests. It was found that the radiation level of some of these areas was as high as three times the background radiation level. To further check this residual activity, and as a matter of routine, a survey was made in the hot cell which contained some equipment used during the winter. In the course of this survey, it was found that some of the equipment was still highly contaminated - one 10-ml beaker which had been used in the La^{140} dilution process still read greater than 20 mr/hr through the beaker side. This beaker was washed and the resulting solution shipped to General Dynamics/Fort Worth for analysis. Results indicated the presence of Eu^{152}, Eu^{154}, Ce^{141}, Pm^{147}, and others, all resulting from the irradiation of minute quantities of impurities in the lanthanum. While the presence of these impurities led to significant long-lived contamination of articles used in handling the undiluted La^{140} samples, the final product of the simulant plant contained the impurities in such a diluted form that noticeable, but not significant, contamination remained after the La^{140} had decayed. It was therefore concluded that a long-term radioactive contamination problem would exist only inside the hot cell at the simulant plant.

A re-survey of the floor in the office area of Bldg. 447 revealed several more spots of fixed Cs^{137} contamination. These were eliminated by removing the top layer of concrete from the floor in the vicinity of the spots. Smears taken from the subject floor area after decontamination exhibited disintegration rates from 9 to 234 dpm per 150 cm^2.

II. LA^{140} SHIPMENTS.

Health physics personnel acted as escorts for transfer of activated lanthanum from Argonne National Laboratory to Camp McCoy on 1, 7, 15, and 22 May 1962.

The La^{140} was transported in the irradiation can inside a Bureau of Explosives approved transfer cask having 6-in.-thick lead walls. During transfer, radiation dose rates measured 2 inches from the exterior surface of the cask ranged from 125 to 170 mr/hr.

The truck used for these transfers was properly posted and dose rates in the truck cab never exceeded 1.5 mr/hr.

III. HOT-CELL AND SIMULANT-PLANT OPERATIONS.

Immediately upon the arrival of the La^{140} at Camp McCoy on the dates noted in the preceding paragraph, hot runs were made in the hot cell and simulant plant. During the hot-cell operations, dose rates were from 150 r/hr at 6 inches to 500 r/hr at 3 inches over the top of the open cask, 130 to 150 mr/hr at the face of the hot cell, 30 to 45 mr/hr at the operator's position, and 2.5 to 13 r/hr at the hot-cell door (non-shielded). During simulant-plant operations, radiation dose rates were 6 to 10 r/hr at the body position during the La^{140} lance change, 5 to 50 r/hr at the La^{140} lance handle, 100 to 135 r/hr along the La^{140} lines, 140 to 350 mr/hr at the empty pan conveyor loading position, and 6 to 22 r/hr at locations where persons worked (max).

IV. TEST-PLOT OPERATIONS.

Health physics personnel monitored and assisted with all operations involving the distribution of fallout simulant and the subsequent decontamination of the areas involved.

In general, the highest personnel exposure rates were encountered during transfer of the radioactive sand from the mixer truck to the spreaders and during operation of the spreaders. Dose rates were as high as 50 mr/hr during the transfer and as high as 900 mr/hr during the spreading. Dose rates to the driver of the mixer truck were as high as 400 mr/hr. Dose rates at the sides of the test plots (scanner operator's position) were as high as 100 mr/hr, and dose rates to the decontamination-equipment operators ranged from 40 to 300 mr/hr.

V. COMPLEX-AREA OPERATIONS.

During blending of the simulant and transfer of the simulant from the mixer truck to the spreaders, dose rates at the mixer controls ranged from 2 to 2.5 r/hr. In the cab of the mixer truck the dose rate was 800 mr/hr.

After the entire complex had been spread, the dose rates above the plot were from 150 to 200 mr/hr. The first decontamination

operation, washing down the building roof, involved dose rates to the operator of 50 to 60 mr/hr. The second operation, shovel-scraping an area extending out to 10 feet from the building sides, involved dose rates to the operators of 80 to 137 mr/hr. The last operation, garden-tractor-plowing the remaining area, involved dose rates to the tractor operator of 20 to 60 mr/hr.

VI. CONTROL OF INGESTION AND CONTAMINATION.

In order to minimize the possibility of ingestion of radioactive material by personnel involved in the test operations, eating was prohibited in the simulant-plant building and in the test areas. Smoking was not possible whenever air contamination was present or suspected, since respirators were required in such instances.

Air samples were collected during each hot-cell and simulant-plant operation. These samples were collected inside the simulant plant, at the simulant-plant exhaust stack, and at the army mess hall situated about 100 yards west of the simulant plant. Results of the samples collected at these locations indicate that moderately high levels ($\leq 2.7 \times 10^{-8}$ μc/cc) of La^{140} contamination were present in the air inside the simulant-plant building during each hot run. Samples collected at the army mess hall indicate that the large dilution factors present at the exhaust stack were sufficient to prevent any significant amount of La^{140} contamination from reaching the mess hall. The mess-hall air samples contained a maximum of 1 $\mu\mu c/m^3$ gross-beta activity (at $T_{\frac{1}{2}} > 1000$ hr), while background air samples collected up to 50 miles from the simulant plant contained a maximum of 1 $\mu\mu c/m^3$ gross-beta activity (at $T_{\frac{1}{2}} \approx 170$ hr).

Personnel contamination was again controlled by the mandatory use of anticontamination clothing and equipment by all persons entering the simulant plant or working on or around the test plots. A change room and decontamination shower were set up at the Health Physics Building, and a shoe-washing station was established at the "hot" entrance to the change area. In spite of these precautions, several instances of skin and hair contamination were discovered at the monitoring station in the change room. None of these cases involved hazardous levels of contamination and all were successfully decontaminated by washing.

Access to all contaminated test plots and areas was controlled through the use of barricades, rope barriers, radiation-hazard signs and "off-limits" signs. There were only a few violations of these controls, none of which resulted in personnel exposure or contamination.

VII. PERSONNEL MONITORING.

Control of personnel exposures was accomplished by the use of film badges and pocket dosimeters. Doses to all personnel were kept under the 3-rem-per-quarter limit, as shown by the exposures to the various groups:

Group	Exposure (mr)
GD/FW personnel	655 - 2970
NDL personnel	265 - 940
Local employees	171 - 660
Visitors	0 - 43

Additional personnel monitoring was accomplished through the use of pre-operational and post-operational urine samples. These were collected at Camp McCoy and sent to GD/FW for routine bioassay. Results of these analyses indicate no significant uptake of La^{140} by any of the persons monitored. Pre-operational urine samples from permanently assigned personnel ranged from 50 to 360 dpm/liter (β,γ activity), with an average of 198 dpm/liter; post-operational urine samples ranged from 27 to 700 dpm/liter, with an average of 280 dpm/liter.

VII. ENVIRONMENTAL RADIOACTIVITY MONITORING.

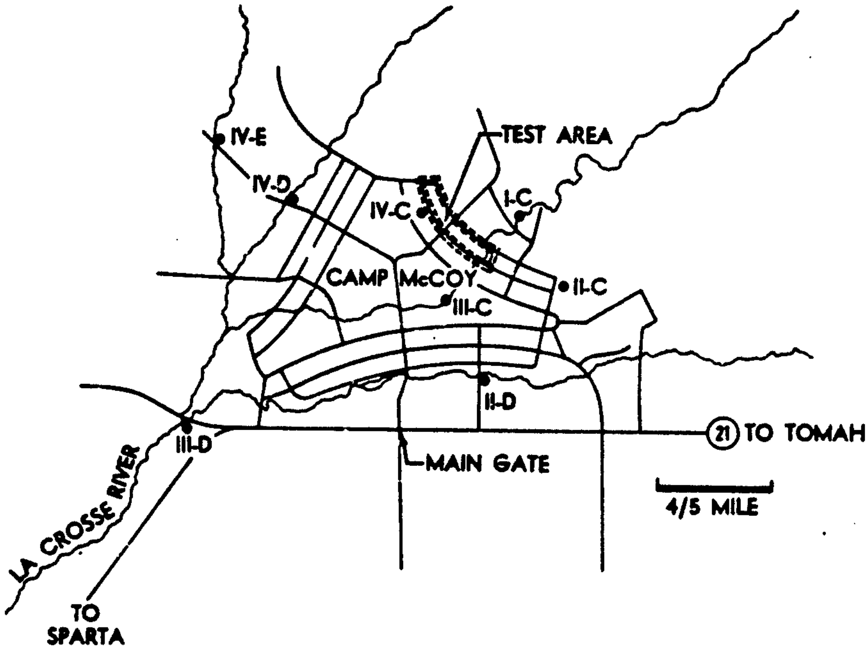
As a continuation of the on-site and off-site environmental monitoring programs initiated in connection with the cold-weather series, three sets of monthly environmental samples were collected during and after the current test series. The sampling-station locations remained unchanged (Figures D.1 and D.2) and the sample types were similar, although several water samples were collected in the last three sets where only snow and ice were available during the winter.

Analysis of these samples of air, soil, water, and vegetation indicates some variation - probably due to nuclear-weapon testing, but no evidence of significant levels of La^{140} contamination from the NDL test program. Tables D.1, D.2, D.3, D.4, and Figure D.3 give the results of analysis of the environmental samples collected in and around Camp McCoy in April, May, and June 1962.

IX. POST-TEST ACTIVITIES.

Following the cessation of test activities, all tools and equipment were decontaminated or allowed to decay to acceptable levels before they were returned to the Camp McCoy authorities.

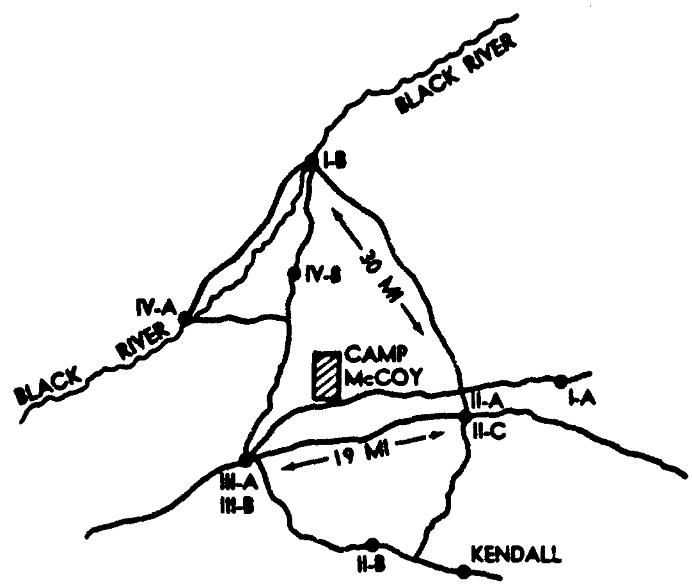
NPC 16,584



STATION	SAMPLE TYPES
I-C	SOIL, SUB-SOIL, WATER, VEGETATION
II-C	SOIL, SUB-SOIL, VEGETATION
II-D	WATER
III-C	SOIL, SUB-SOIL, WATER
III-D	WATER, VEGETATION
IV-C	SOIL, SUB-SOIL, VEGETATION
IV-D	WATER
IV-E	WATER, SOIL

Figure D.1 - On-Site Environmental Sampling Locations

NPC 16,886



STATION	LOCATION	SAMPLE TYPES
I-A	WYEVILLE	CREEK WATER, SOIL, SUB-SOIL, VEGETATION
I-B	BLACK RIVER FALLS	RIVER WATER, SOIL, SUB-SOIL, VEGETATION, AIR
II-A	TOMAH LAKE	LAKE WATER, SOIL, SUB-SOIL, VEGETATION
II-B	WILTON	CREEK WATER, SOIL, SUB-SOIL, VEGETATION
II-C	TOMAH	DRINKING WATER, AIR
III-A	SPARTA LAKE	LAKE WATER, SOIL, SUB-SOIL, VEGETATION
III-B	SPARTA	DRINKING WATER, AIR
IV-A	MELROSE	RIVER WATER, SOIL, SUB-SOIL, VEGETATION
IV-B	CATARACT	CREEK WATER, SOIL, SUB-SOIL, VEGETATION
	KENDALL	AIR

Figure D.2 - Off-Site Environmental Sampling Locations

TABLE D-1

RADIOACTIVE CONTENT OF SOIL SAMPLES
($\mu\mu c/gm$)

Station	April	May	June
I-A	5.53 ± 2.57	9.85 ± 2.44	24.52 ± 2.81
I-B	30.65 ± 2.81	26.40 ± 2.67	49.62 ± 3.00
I-C	33.07 ± 3.00	71.25 ± 3.38	13.83 ± 2.64
II-A	18.20 ± 2.48	16.39 ± 2.71	68.32 ± 3.19
II-B	26.98 ± 2.88	33.80 ± 2.68	35.88 ± 2.68
II-C	45.63 ± 3.14	36.30 ± 2.83	41.58 ± 2.78
III-A	32.37 ± 2.99	22.83 ± 2.67	58.10 ± 3.28
III-C	131.57 ± 4.24	56.31 ± 3.32	42.17 ± 3.45
IV-A	9.75 ± 2.35	19.69 ± 2.62	44.26 ± 2.97
IV-B	13.83 ± 2.67	25.08 ± 2.65	21.44 ± 2.77
IV-C	89.22 ± 3.68	31.82 ± 2.82	29.55 ± 2.86
IV-E	42.92 ± 3.16	42.77 ± 3.13	43.56 ± 2.81
Average	39.98 ± 3.00	32.71 ± 2.83	39.40 ± 2.94

TABLE D-2

RADIOACTIVE CONTENT OF SUB-SOIL SAMPLES
($\mu\mu c/gm$)

Station	April	May	June
I-A	5.53 ± 2.52	0 ± 3.18	4.77 ± 2.47
I-B	6.13 ± 2.47	8.55 ± 2.50	19.45 ± 2.35
I-C	24.83 ± 3.15	33.20 ± 2.89	6.23 ± 2.51
II-A	26.28 ± 2.85	.68 ± 2.58	16.77 ± 2.46
II-B	30.25 ± 2.96	28.84 ± 2.88	29.55 ± 2.83
II-C	2.72 ± 2.48	0 ± 2.30	7.26 ± 2.20
III-A	13.83 ± 2.68	4.92 ± 2.59	12.45 ± 2.60
III-C	11.07 ± 2.62	3.46 ± 2.81	30.64 ± 2.74
IV-A	3.41 ± 2.43	2.86 ± 2.45	25.48 ± 3.92
IV-B	9.03 ± 2.77	0 ± 2.21	46.34 ± 3.16
IV-C	7.61 ± 2.54	32.35 ± 2.91	14.29 ± 2.42
Average	12.79 ± 2.68	10.17 ± 2.66	19.39 ± 2.70

TABLE D-3

RADIOACTIVE CONTENT OF VEGETATION SAMPLES
[μμc/gm (ash)]

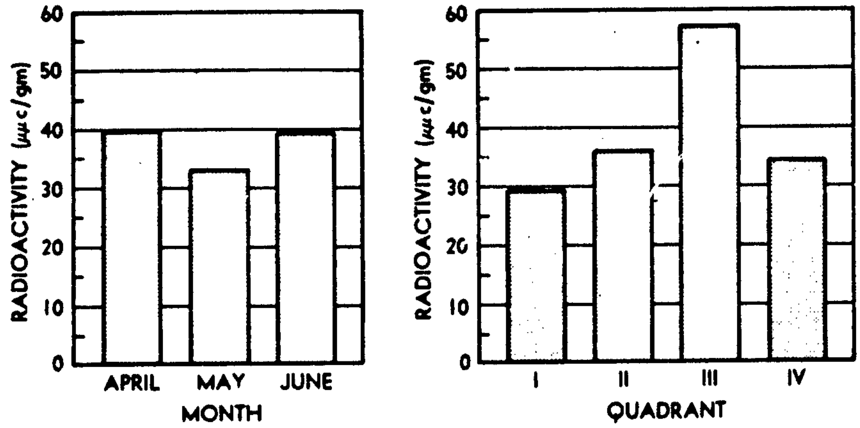
Station	April	May	June
I-A	6393.17 ± 56.52	1194.46 ± 20.95	598.78 ± 27.26
I-B	7376.61 ± 87.93	1364.26 ± 28.47	1333.13 ± 29.82
I-C	5846.31 ± 58.00	1839.65 ± 33.83	1109.20 ± 27.39
II-A	3439.11 ± 40.20	2389.59 ± 50.28	641.87 ± 22.38
II-B	682.55 ± 19.93	1108.05 ± 25.35	823.85 ± 21.34
II-C	5175.95 ± 94.51	1172.38 ± 31.91	1949.22 ± 36.24
III-A	827.31 ± 22.70	1455.55 ± 22.62	945.26 ± 23.40
III-D	3173.39 ± 43.22	1096.93 ± 15.20	1088.80 ± 24.01
IV-A	6429.34 ± 58.96	869.96 ± 17.53	1961.23 ± 32.83
IV-B	1672.16 ± 30.75	3304.65 ± 44.28	670.16 ± 19.01
IV-C	7886.99 ± 70.59	2896.40 ± 40.49	1062.27 ± 27.58
Average	4445.72 ± 53.03	1699.26 ± 30.08	1107.62 ± 26.48

TABLE D-4

RADIOACTIVE CONTENT OF WATER SAMPLES
(μμc/liter)

Station	April	May	June
I-A	30.02 ± 18.28	114.87 ± 21.21	90.79 ± 21.14
I-B	18.76 ± 18.11	49.55 ± 17.98	38.13 ± 17.46
I-C	11.84 ± 20.54	15.77 ± 17.[illegible]8	0 ± 18.71
II-A	3.74 ± 18.76	38.53 ± 18.13	37.86 ± 19.02
II-B	7.27 ± 18.47	281.53 ± 24.85	3.87 ± 18.63
II-C	7.39 ± 18.14	19.39 ± 18.19	12.41 ± 19.65
II-D	3.63 ± 17.69	21.53 ± 18.14	6.71 ± 16.61
III-A	22.52 ± 17.97	10.90 ± 20.51	0 ± 18.14
III-B	0 ± 23.45	-- --	0 ± 18.08
III-C	32.18 ± 18.55	11.06 ± 20.29	17.34 ± 17.06
III-D	25.54 ± 17.94	36.84 ± 18.68	16.86 ± 15.65
IV-A	30.27 ± 18.52	163.38 ± 18.74	69.17 ± 18.38
IV-B	10.88 ± 18.49	36.33 ± 17.94	0 ± 16.94
IV-D	10.97 ± 17.92	15.00 ± 18.92	17.76 ± 17.00
IV-E	7.27 ± 17.69	10.82 ± 19.95	3.60 ± 18.36
Average	14.82 ± 18.70	58.96 ± 19.34	20.97 ± 18.06

(a) Soil Samples



(b) Sub-Soil Samples

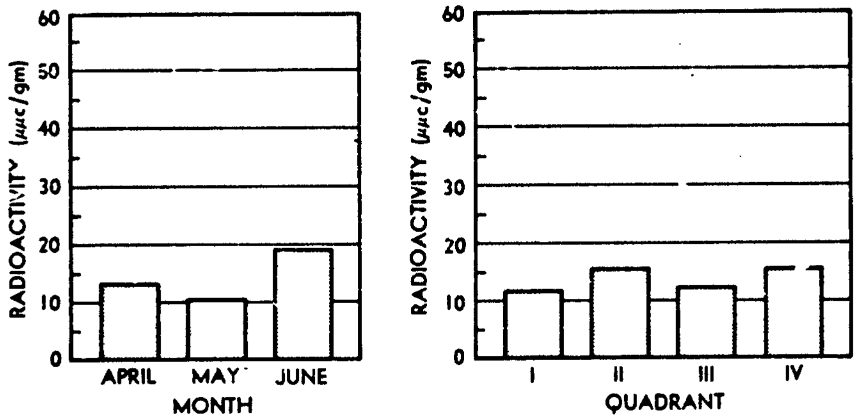


Figure D-3 - Radioactivity of Environmental Samples

(c) Vegetation Samples (Ash)

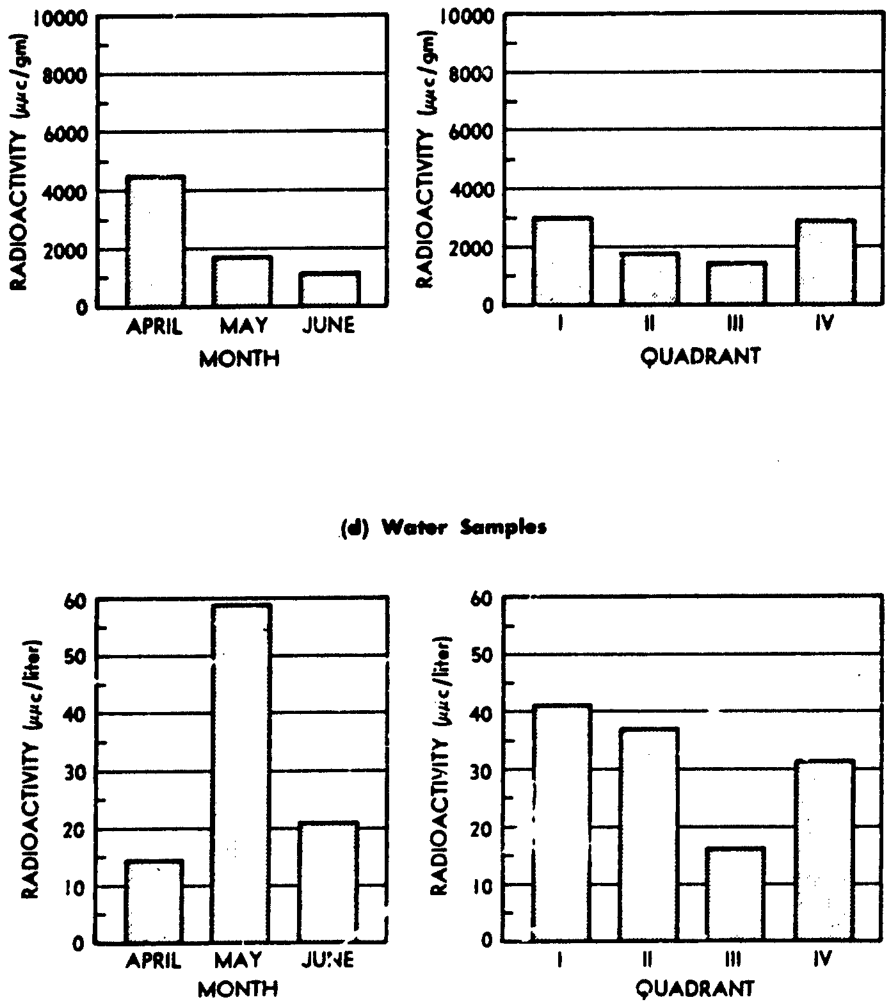


Figure D-3 (Cont'd) - Radioactivity of Environmental Samples

Buildings and areas contaminated in the course of the test program remained posted and barricaded until the contaminating material had been removed or had decayed to acceptable limits. As of 13 June 1962 analysis of the smear samples, soil samples, and surveys showed that with the exception of the simulant-plant building, all buildings and areas could be returned to normal use. The simulant plant, however, contained a quantity of La^{140} contaminated sand and residual radioactivity in significant amounts. This building was therefore locked and posted with "radiation area" signs and the key given to the Post Engineer at Camp McCoy.

Moderate-level radioactive waste removed from the buildings and areas, such as contaminated sand, was buried in a locked, controlled-access area.

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Joseph C. Maloney and John L. Meredith

NDL-TR-33, September 1962 - UNCLASSIFIED Report

This project was conducted to determine the effectiveness achieved, the effort required, and the dose received by personnel in the use of simple decontamination procedures for the radiological recovery of residential areas. Fall-out simulant was prepared by tagging 150μ to 300μ sand with lanthanum 140. The simulant was dispersed onto lawns, paved areas, and roofs. Decontamination techniques using household and garden tools were evaluated. In addition, the radiological recovery of a small residence and surrounding lawn was effected.

1. Decontamination
2. Radioactive Fallout
3. Civilian Defense Systems

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